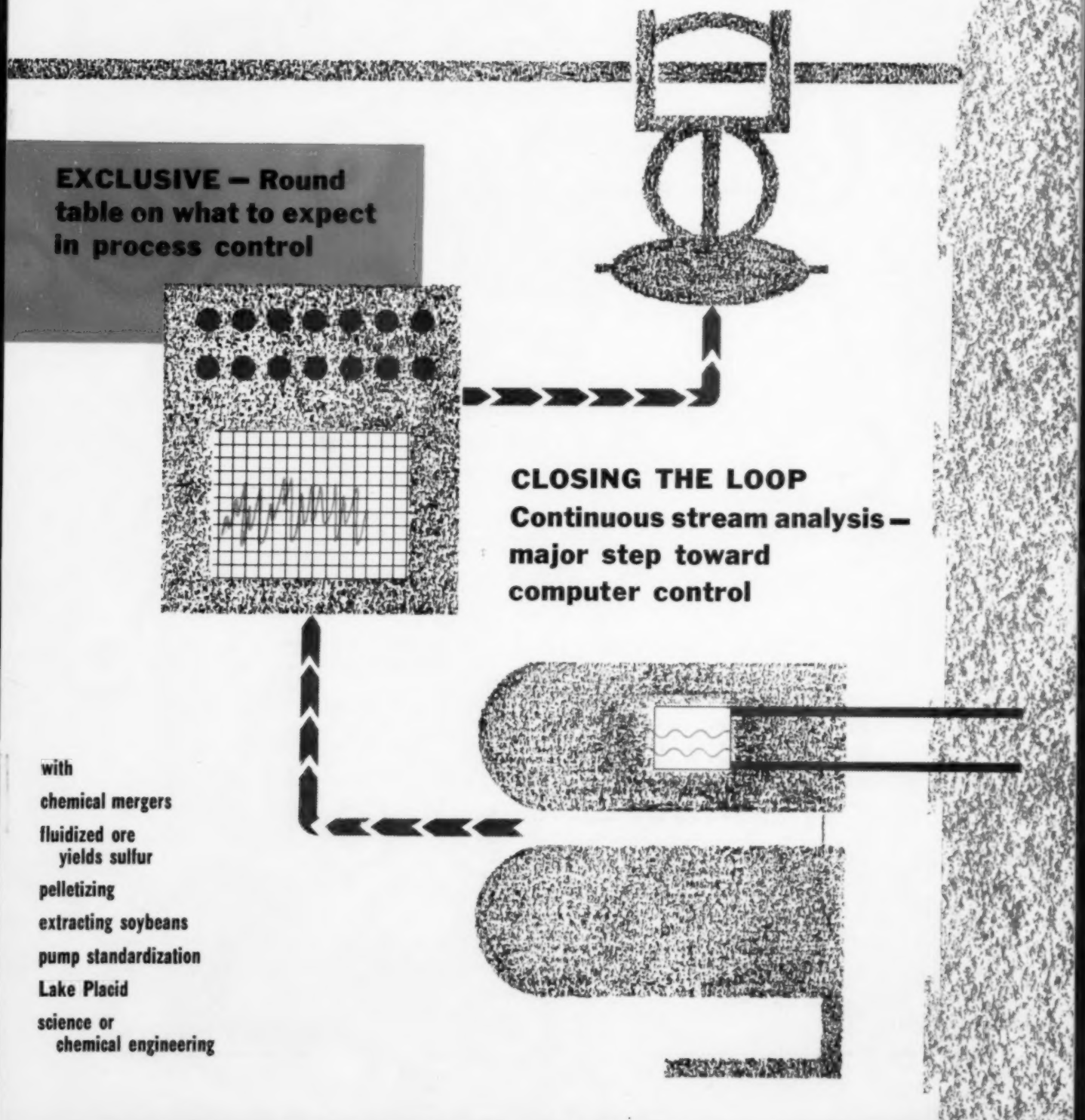
Chemical Engineering Progress

Special —
how Celanese separates its petrochemicals

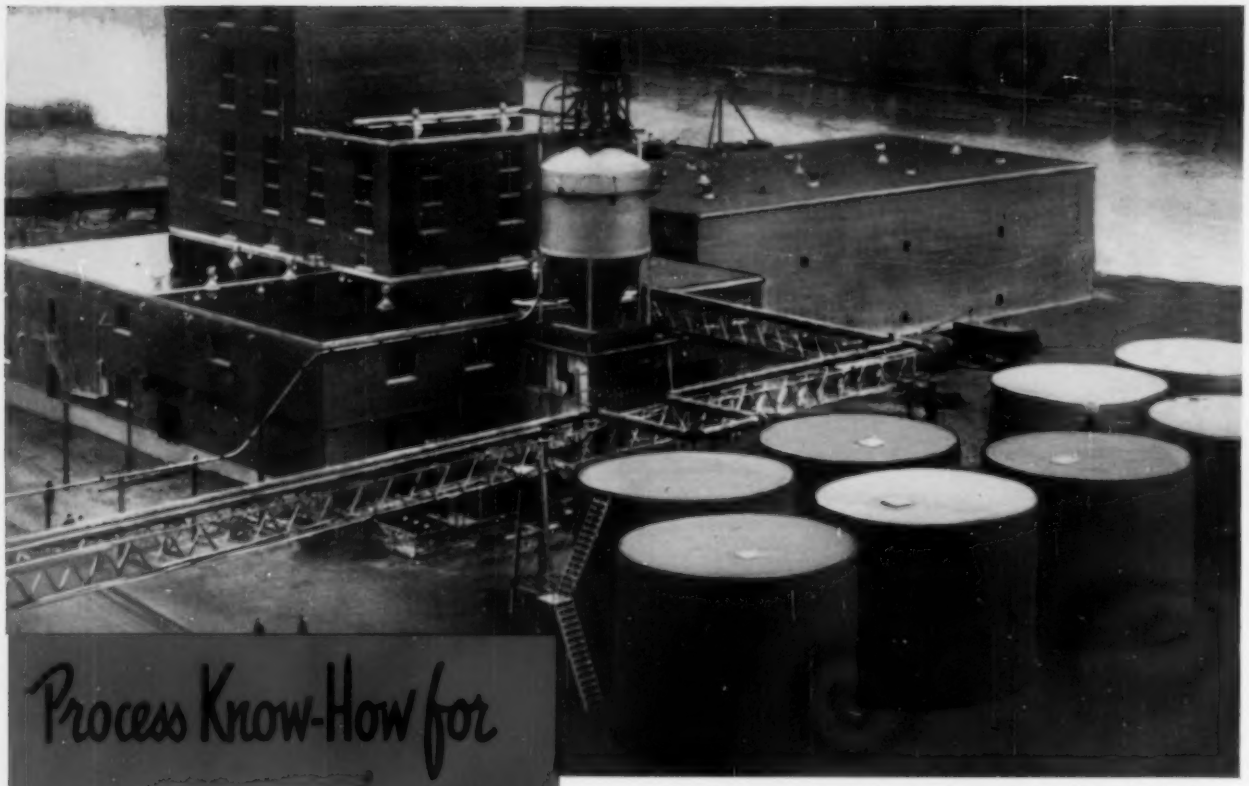
AUGUST 1955



EXCLUSIVE — Round table on what to expect in process control

CLOSING THE LOOP
Continuous stream analysis — major step toward computer control

with
chemical mergers
fluidized ore yields sulfur
pelletizing
extracting soybeans
pump standardization
Lake Placid
science or chemical engineering



Vulcan-designed ethanol plant utilizing waste sulfite pulp liquor

Process Know-How for WASTE UTILIZATION

- **CONVERSION OF WASTES**
- **RECOVERY AND REFINING OF BY-PRODUCTS**
- **DISPOSAL OF PROCESSED RESIDUES**

Vulcan Engineering Division has designed and built systems for translating problems of wastes into opportunities for profits. Companies—particularly those engaged in wood-pulping operations — should examine their problems of wastes and stream or air contamination in the light of this experience. Vulcan installations for turning wastes into profits include those for . . .

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- Recovery of sulfur dioxide from pulp digester gases
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- Preliminary economic evaluations of applicable processes
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Chemical Engineering Progress

AUGUST, 1955 • Volume 51, No. 8

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this month's theme

Four articles on process control provide up-to-date views and methods which should be of interest to every chemical engineer who may have any part in deciding—now or in the future—what steps will be taken to make his process more automatic in operation.

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For a brief description of each article . . . see "What's In This Issue"—page 31.

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1 **LOWER MAINTENANCE:** Rockwell-Nordstrom valve lubrication is *preventive* maintenance that eliminates metal-to-metal friction and stops most valve maintenance problems before they start. Cost records in hundreds of chemical plants prove that lubrication is far less expensive than even routine maintenance (reseating, packing, etc.) on ordinary valves.

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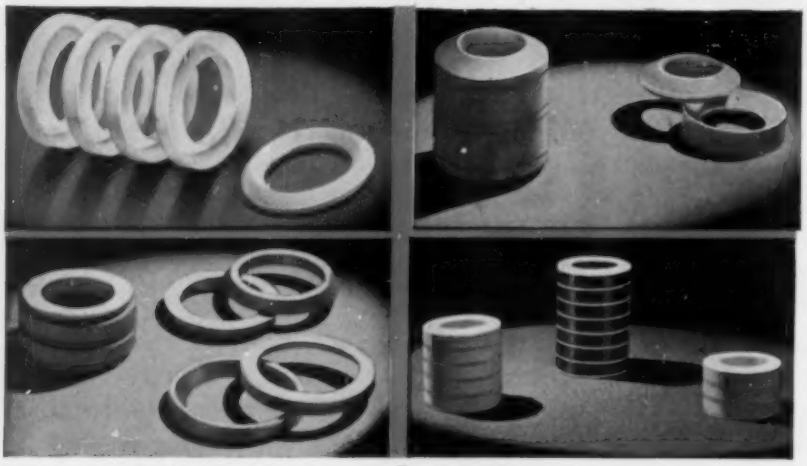

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LETTERS TO THE EDITOR

What to Read on Management

. . . Incidentally, there have been many excellent books and papers published on this general subject [writer refers to papers and articles on management, organizational planning, etc.], and it seems to me that abstracts or competent reviews might be of interest to members of the Institute. Just to mention a few references that I think would reflect the caliber of thought you should repeat in C.E.P., I list the following:

The Practice of Management, by Peter F. Drucker

Management of Expanding Enterprises

What Makes An Executive

(These books are the outgrowth of discussion at two Round Tables held under the auspices of the Graduate School of Business of Columbia University.)

GEORGE E. HOLBROOK

Wilmington, Del.

We Regret the Slip

On page 90 of the June issue of CEP, which I received on *June 20*, I note that I may object to the election of any candidates for members if I send in my objection prior to *May 15*. Sounds to me as if the Admissions Committee is trying to railroad someone into the Institute!

W. L. FAITH

Los Angeles, California

∫ Typographical error! That *May 15* date should have been *July 15*.

EDITOR

NOTED AND QUOTED

Nuclear Energy and Engineering Education

The problems facing our engineers and scientists are ever increasing in complexity. . . One hundred years ago the engineering program was four years for a bachelor's degree. This is still the basic stem of our engineering educational programs throughout the country. One hundred years ago the formal education of a medical doctor usually took about one year, and this was followed by a year or two of practical experience under the guidance of a competent practitioner. The basic program for an M.D. is now seven years plus two years experience as an interne. . . . Perhaps the time has come to establish a basic professional program of six or seven

(*Continued on page* 10)

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little drip
costs you money!

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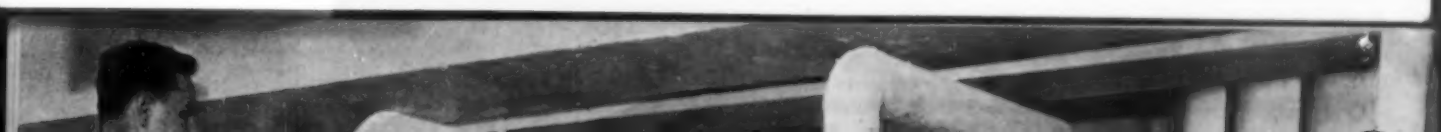

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BY 2,500,000 FILTER CHANNELS PER SQ. IN.!
A Celite Filter Cake is hundreds of times finer than the finest wire mesh!
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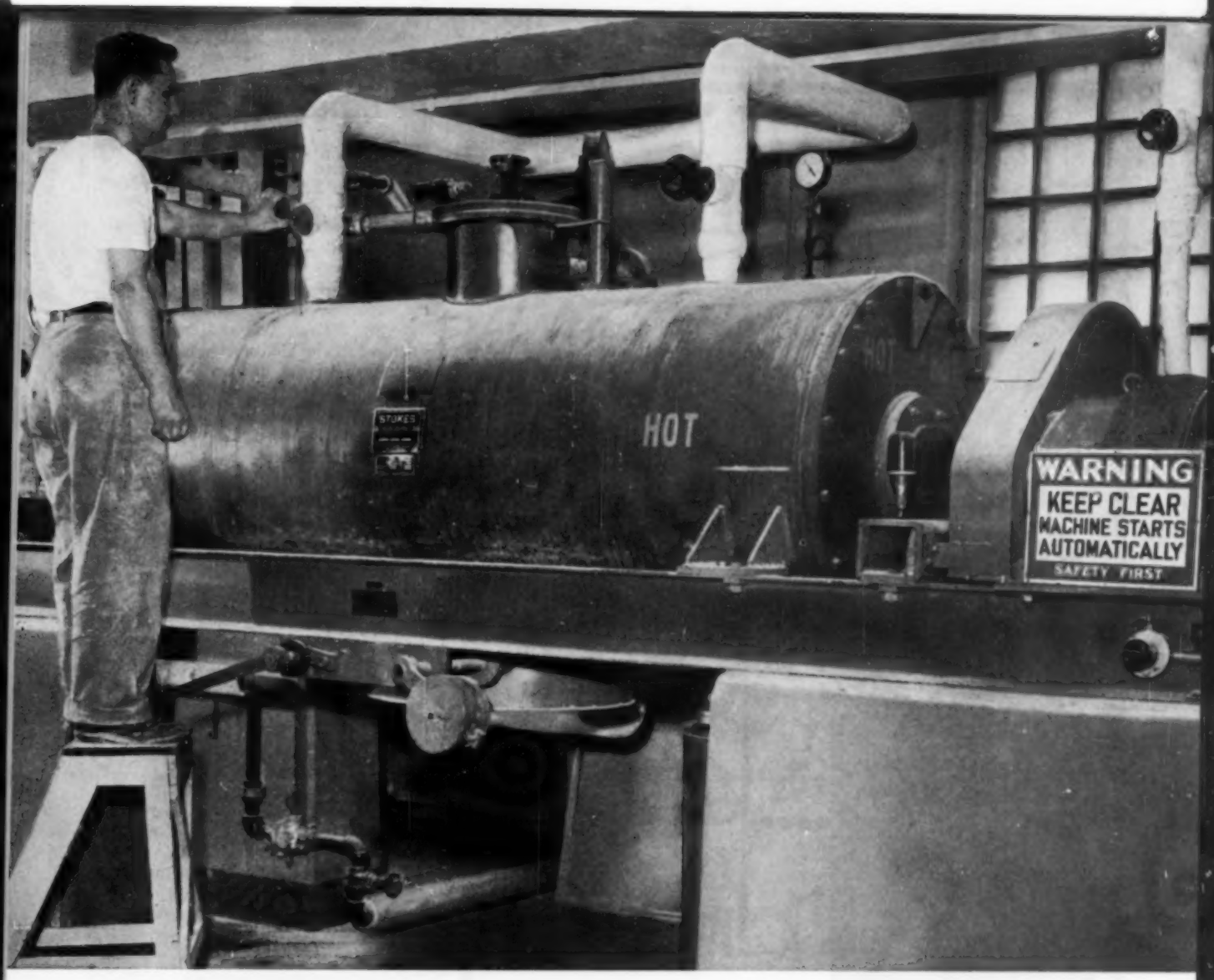

Weed-killer production problem solved by STOKES vacuum dryer

A leading chemical manufacturer asked us, "What equipment can we use to dry 6 tons per day of a heat-sensitive weed-killer from a true solution containing 67% dissolved solids to a crystalline product of 99.75% solids? Maximum allowable temperature is 50° C and we must crystallize and dry in one operation."

Stokes engineers developed the answer from broad experience with drying problems . . . confirmed it by tests on the chemical in the fully equipped Stokes laboratory . . . recommended a Stokes rotary vacuum dryer sized to give the needed production on a predetermined drying cycle. The unit was purchased and is now on the production line.

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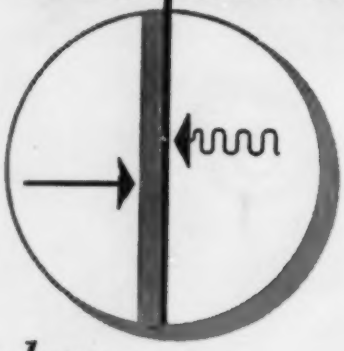
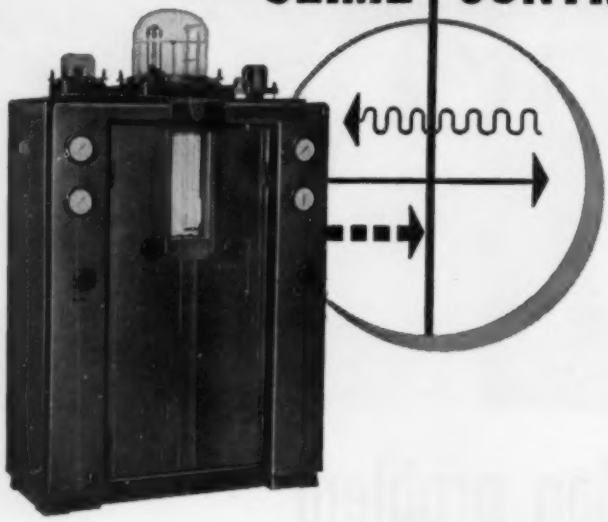


Be sure you have

SLIME | CONTROL



Whether you heat or cool water for make-up, process or any other use, you will need Wallace & Tiernan Chlorination to help combat slime problems introduced by water-borne bacteria or air-borne bacteria.

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CD-39

NOTED AND QUOTED

(*Continued from page 6*)

years for the truly professional engineer who will be capable of carrying forward the developments which appear clearly ahead.

The sources of energy to meet all of our requirements are available to us. We appear to have the necessary time. Have we the scientific and engineering imagination and abilities to meet the expanding desires of the human race?

George Granger Brown
Centennial Convocation of New York University's College of Engineering

Essential Qualities in Preparation for Engineering Career

It is an obvious absurdity to attempt to teach so many things that the student will be prepared to meet most of the situations he will encounter–even in his professional life, to say nothing of his personal life; the effort should, rather, be largely directed toward the development of those qualities that will help him most in coping with whatever situations he may encounter. . . .

What, then, are these qualities? . . . The emotional qualities would include those such as sympathy and kindness; the moral, those such as honesty and responsibility; the physical, those such as health and vitality; and the mental, those such as intelligence and imagination. While recognizing the full importance of the first three categories—the emotional, the moral, and the physical, they tend to lie outside the province of the strictly academic program. . . .

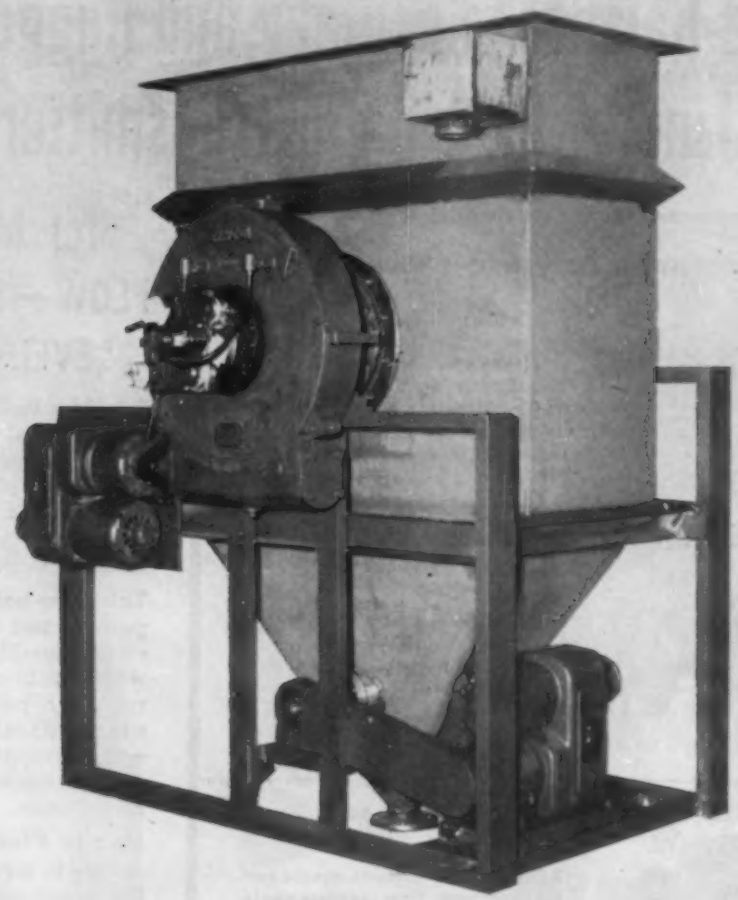
John B. Wilbur
"The Limitations of Logic in Engineering Education"
The Technology Review

Is Selling in Step with Automation?

Automatic controls can produce goods but someone must sell them. In today's and tomorrow's tight competitive market, in which our nation's consumers have plenty to choose from, U. S. industry will have to draw upon all its merchandising and sales abilities to make certain that the market buys what our vastly expanded and increasingly automatic industry produces. . . . We in the automation business know that automation produces better goods. It produces them at savings which should make them irresistible to the average buyer, if the economics of mass production were passed along to him . . .

C. L. Peterson
Minneapolis-Honeywell Regulator Co.

(*Marginal Notes on page 14*)



Another Eimco Continuous Vacuum Filter

The machine pictured is built as two different machines. One contains a drum type filter with a top feed for drying sand or other crystalline materials. The other contains a disc type thickener filter which runs completely submerged. It is built with a large port for carrying the clarified product or filtrate and a small port arranged to admit a small amount of blow at the bottom sector for dislodging the thickened material so that it can be discharged at the bottom of the tank.

These are special filter applications and examples of developments in liquid-solids separation through filtration.

Eimco, with more than half a century of experience in serving the process industries, makes drum, disc, pan, pressure, plate and frame and tubular type filters with numerous attachments that can be applied to processing industries with difficult filtration problems.

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Available with differential ranges as low as 0—0.6" H_2O (ranges this low are exclusive with the Republic Transmitter) and as high as 0—750 psi. Range may be suppressed up to 80% of full scale for density or level measurements.

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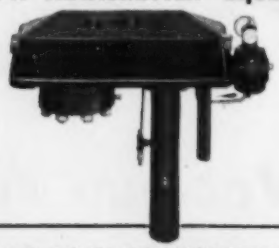
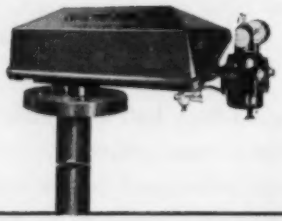
Pressure ranges from 0—1" H_2O to 0—2000 psi. May be easily adapted for absolute pressure ranges from 0—25 mm Hg to 0—100 psia.

FLOW TRANSMITTER—Square Root Extracting Type



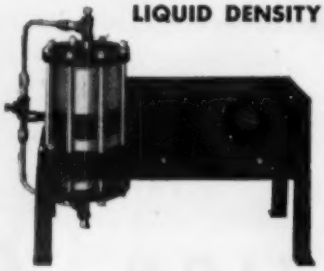
Automatically extracts square root function from flow measurements, permitting use of uniformly graduated charts and linear control devices. Available in all standard differential ranges.

LIQUID LEVEL TRANSMITTER—Bouyancy Type



Ranges to suit most applications. Can be used to measure level in closed tanks under pressure. Can also measure liquid-to-liquid interface.

LIQUID DENSITY TRANSMITTER—Bouyancy Type



Makes continuous density measurement of flowing liquids at line pressures to 300 psi. Fast response.

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Special electrical meter body available for use with most Republic Pneumatic Transmitters. Permits locating pneumatic transmitter at metering point to cut piping costs and keep dangerous fluids out of control rooms.

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These are but a few of the many features found in Republic force-balance Transmitters. Write for a free copy of Data Booklet with all of the details and complete description of various types.

*In a force-balance pneumatic transmitter, a force produced by the process variable is balanced against a pneumatic pressure. The amount of air pressure required to produce a balance is proportional to the process variable and may be conducted to remote reading instruments or used as the measuring impulse for an automatic controller.

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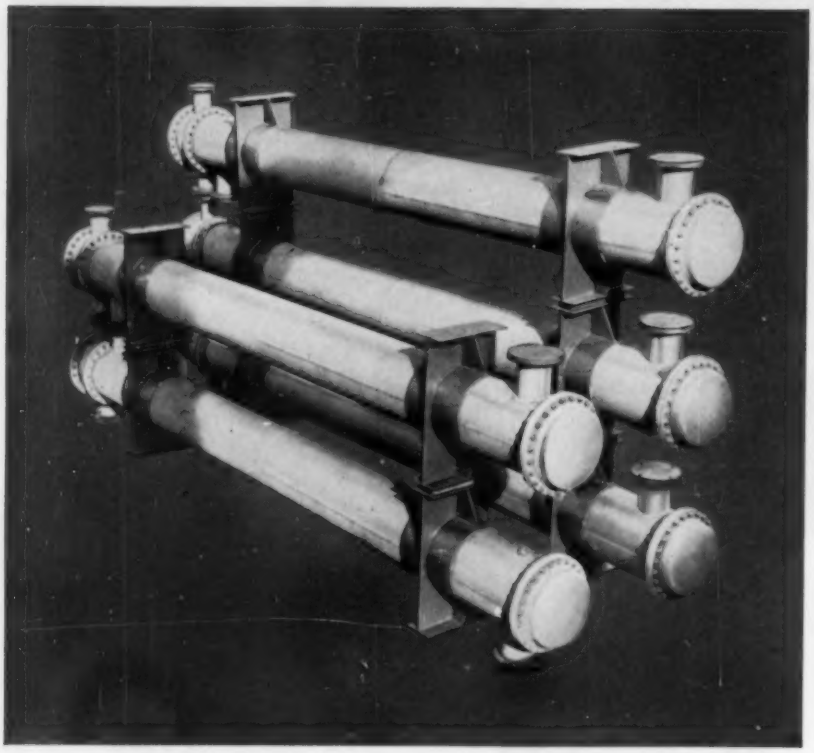

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CONTAINERS AND PRESSURE VESSELS FOR GASES, LIQUIDS AND SOLIDS

MARGINAL NOTES

Proceedings of Belgium Congress. Industrie Chimique Belge, Brussels, Belgium (1955), 2,000 pages, $19.00.

The text of the scientific papers presented at the 27th International Congress of Industrial Chemistry held in Brussels, Belgium, September 11 through 19, 1954, is published in two volumes.

The first volume was available in April and the second in July, 1955. Subscriptions are now being accepted at the Federation des Industries Chimiques de Belgique, 32 rue Joseph II, Brussels, Belgium.

Chemical Engineering. Vol. 1. Fluid Flow, Heat Transfer and Mass Transfer. J. M. Coulson and J. F. Richardson. McGraw-Hill Book Co., Inc., New York, and Pergamon Press, Ltd., London (1954). 370 pages, $7.50.

Reviewed by Shelby A. Miller, Department of Chemical Engineering, University of Kansas, Lawrence, Kansas.

This book is the first comprehensive exposition of the principles of unit operations to come from British chemical engineers. It promises a valuable two-volume text when the final volume appears.

Volume 1 deals with some of the fundamentals of technical chemical engineering—fluid flow, heat transfer, and diffusion—with added chapters on units and dimensions, pumps, and humidification. The treatment is generally sound, thorough, and contemporary. Many of the more theoretical and mathematical passages are in fine print to permit their easy omission by the once-over-lightly reader; but to neglect these passages, is to lose the basic quality of the book.

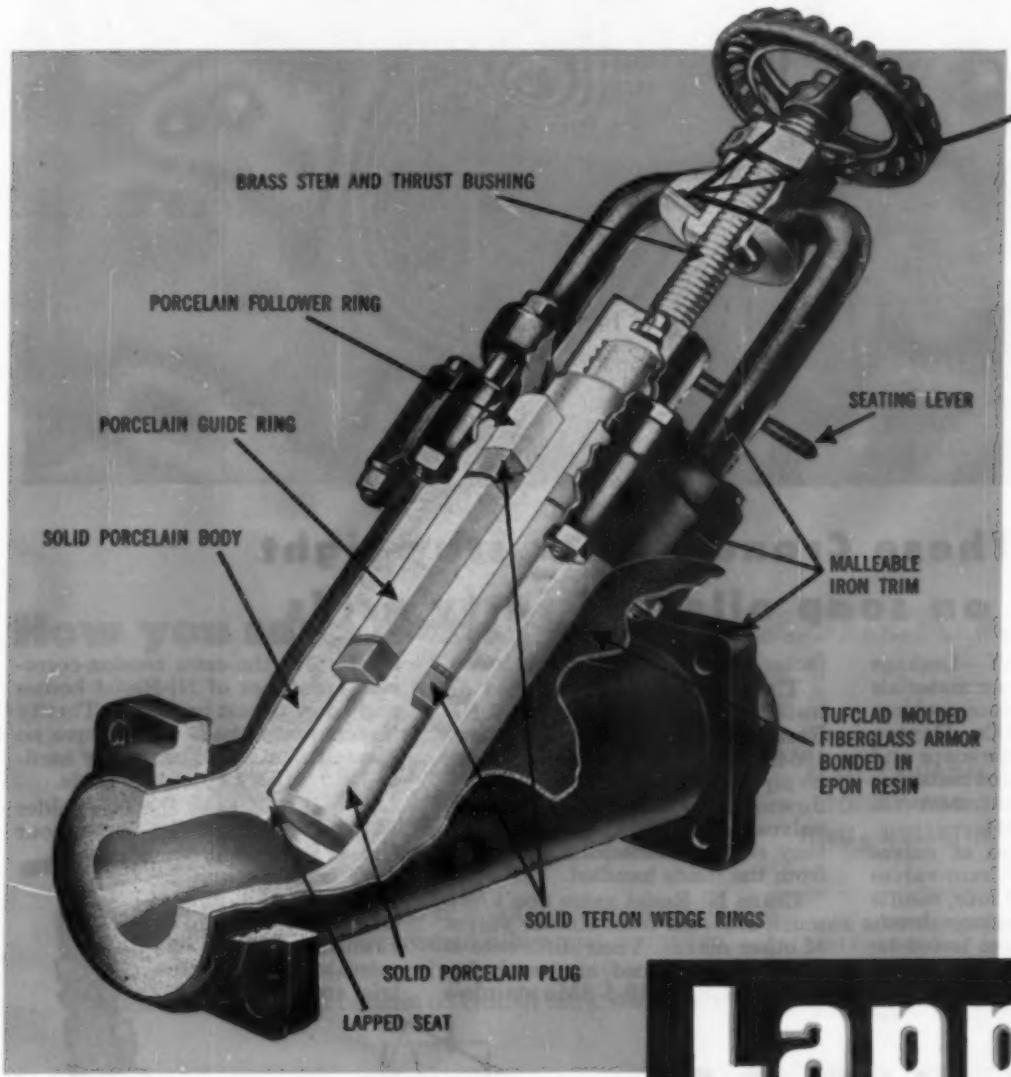
The book is at its best in the three chapters on mass transfer and boundary layer theory. Chapter 8, the analogy between momentum, heat, and mass transfer, is an outstanding summary of the subject. Other features of merit are the introduction to the chapter on pipe friction, the inclusion of open-channel flow, and the nearly monographic chapter on heat transfer.

On the debit side, the chapter on flow measurement is substandard because of carelessness and ambiguity. It illustrates the authors' occasional practice of turning approximations into equalities without due warning, and it contains most of the book's mechanical errors. Among other items that disturbed the reviewer are the use of a friction factor that is different from Perry's and Brown's; listing of Moody's values of absolute roughness that are in feet as inches; and omission of liquid metals in

(*Continued on page* 18)

A "cushioned" porcelain-to-porcelain seal in the Lapp Valve

The chemical resistance qualities of the Lapp Valve come from the fact that the body and plug are both *solid porcelain*. Porcelain, as a material, however, has little resiliency or "give" when the plug hits the seat in the body. Special spring-loaded "cushion" seating in Lapp valves prevents damage from a heavy-handed operator, and warns when seal is tight. Built into the thrust bushing of every Lapp Y-valve and angle valve, is an arrangement of tempered Beryllium copper spring washers. This spring loading also provides that a closed valve will maintain its tightness even under vibration and thermal movement of parts.



V-valves, angle valves, flush valves, safety valves, and plug cocks of Lapp Porcelain have standard bolt-circle flanges for easy connection to all piping and equipment. Write for bulletin with complete description, characteristics, and specifications. Lapp Insulator Co., Inc., Process Equipment Division, 462 Wendell St., LeRoy, N. Y.

Lapp

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These Crane valves stay tight on soap oils and fatty acids

THE CASE HISTORY—Leakage through valve seats in raw materials supply lines posed a serious problem for Davies-Young Soap Co., Dayton—makers of various type soaps and cleaning fluids. Unwanted materials leaking past metering stations would infiltrate processing vats.

Four different makes of valves were tried before these Crane valves were installed. With all four, results were the same—seat leakage developed quickly; the valves lasted no more than 4 to 8 weeks.

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The condition was remedied on installation of Crane No. 1670 Ni-Resist cast iron valves in January 1954. Eighteen months later—with no piping maintenance and no shutdowns whatsoever—the Crane valves are still holding tight. And they show no deteriorating effects from the fluids handled.

Crane Ni-Resist gates don't *look* much different from similar valves of other makes. Their difference is in properly designed, accurately finished seating of 18-8 SMo stainless steel—plus the *extra* erosion-corrosion resistance of Ni-Resist bodies and bonnets cast by Crane. Thrifty buyers know these valves have no "equal" for handling many hard-to-hold, mildly corrosive fluids.

You should have the new folder (AD2047) on these valves. Ask your Crane Representative for a copy, or write to Crane Co., General Offices, Chicago 5, Ill. Branches and Wholesalers serving all industrial areas.

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MARGINAL NOTES

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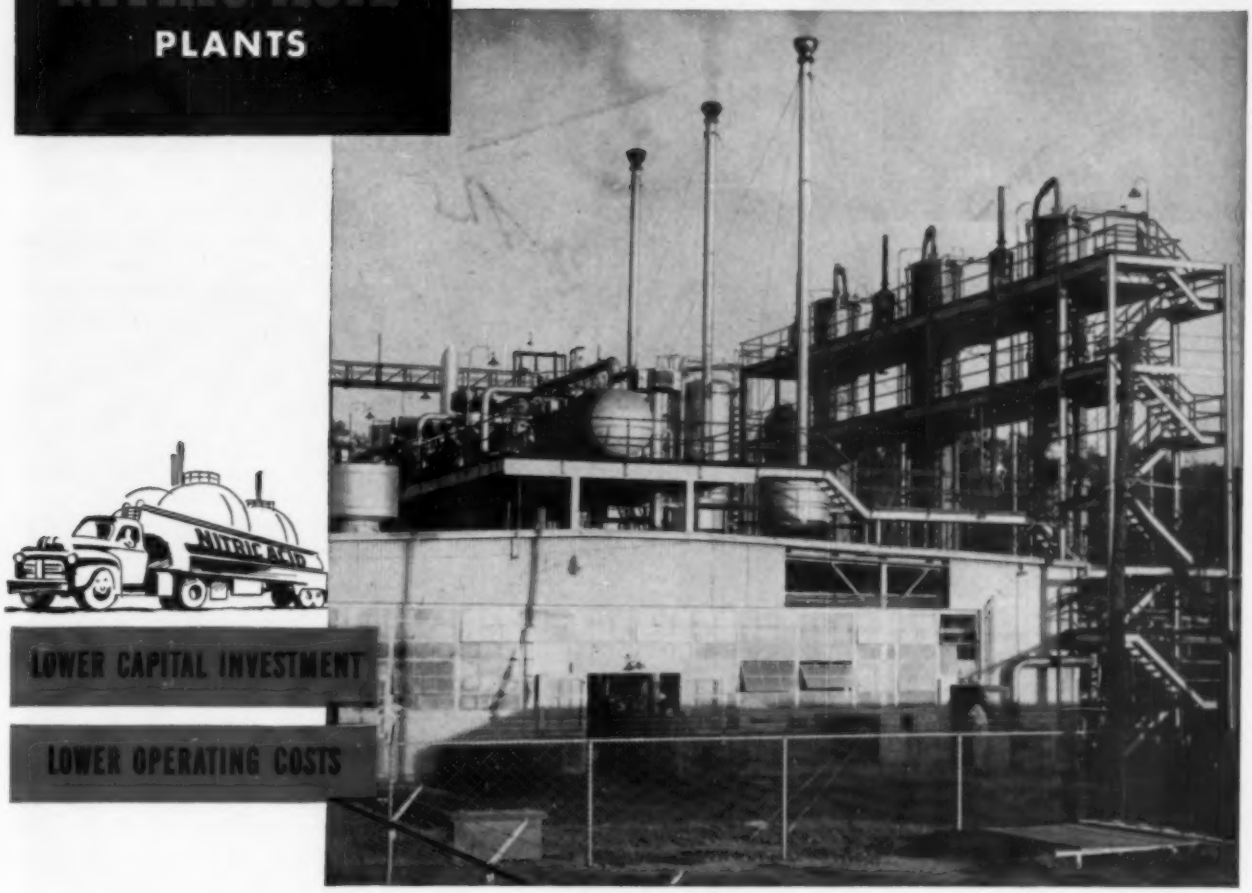
Girdler nitric acid plants employ the well-known Du Pont process, using high-pressure catalytic oxidation, to produce nitric acid. These plants offer greater economy, in both investment and operating costs, than atmospheric or low-pressure units. With the high-pressure process 55%-60% nitric acid is produced with efficient use of catalysts, and with lower utility requirements.



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WHEN you come to Girdler for nitric acid facilities, you get the benefit of the vast experience of DuPont as well as Girdler. DuPont's agreement with Girdler has combined the know-how of both companies. Moreover, Girdler has unsurpassed experience in building plants for the production of ammonium nitrate.

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Verti-Line PUMPS

were first—
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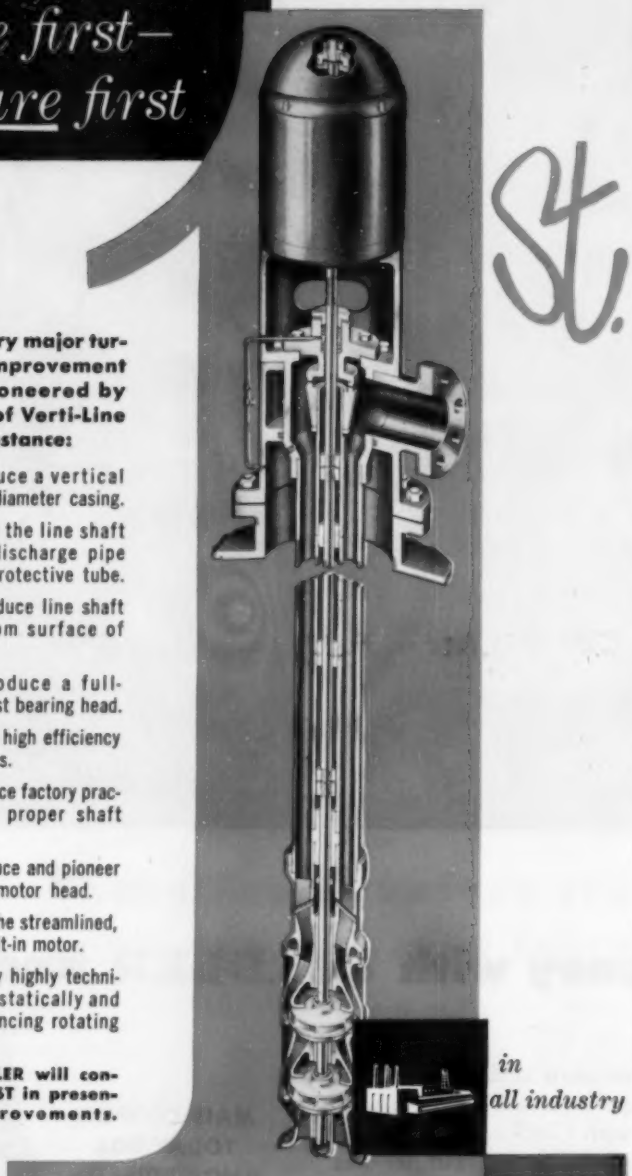

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first to produce a vertical pump for small diameter casing.

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first to introduce line shaft lubrication from surface of ground.

first to introduce a full-floating ball thrust bearing head.

first to design high efficiency enclosed impellers.

first to introduce factory practices to insure proper shaft alignment.

first to introduce and pioneer the hollow-shaft motor head.

first to adopt the streamlined, weatherproof, built-in motor.

first to employ highly technical methods for statically and dynamically balancing rotating parts.

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MARGINAL NOTES

(*Continued from page* 14)

discussion of heat-transfer coefficients. U. S. engineers may accept absolute units, used consistently throughout the text, with some distaste, and may object to some of the nomenclature.

However, readers of Volume 1 will look forward eagerly to Volume 2 which will deal with the individual unit operations.

Two Ears of Corn, Two Blades of Grass. D. H. Killeffer. D. Van Nostrand Company, Inc., New York, N. Y. (1955), 139 pages, illustrated, $4.00.

In authoritative language, yet easily read, this work by Killeffer gives a good account of our chemical accomplishments in the laboratory, in the research organization, in the plant and, out of this worth-while record the author strikes an optimistic note for a future, peaceful and prosperous, if only American brains and well-trained minds go to work.

Here is rewarding reading for those perplexed over a world where malnutrition, disease, and war claim so many victims. The author's thesis is that universal peace can be surely realized by applying technology and science through human cooperation and collaboration to solve the basic problems of diet, health, and resources. He pleads for a chemical technology and an appreciative understanding of it which will enable us to change whatever we have in plenty into what we want and need.

No dilettante in the study of cause and effect, Mr. Killeffer, author of "Eminent American Chemists," "The Genius of Industrial Research," and other works is on familiar ground when he discusses the art of synthesis and the evolutionary processes involved in the marketing of synthetic products. In this picture he highlights the experiences of World War I days when this country found itself in desperate need of dyes and drugs and had no knowledge of German "ersatz." But out of such painful experiences a chemical industry was born and nurtured so that the present generation of Americans can live longer and happier lives.

Coming closer to the present time he tells the story—the dream and the reality—of antibiotics, including penicillin, streptomycin, and other drugs which fight disease; ultraviolet rays and their effect on rickets; plant breeding; and quick freezing. He recounts those many blessings which we take so casually but which scientists and industrialists struggled over long and hard for the betterment of man.

(*Continued on page* 24)

why STAINLESS STEEL TUBING?

Selection of the proper grade of stainless steel tubing is essential because no single metal or alloy economically resists all corrosive conditions. As certain physical properties are required for specific applications, sometimes the consideration of corrosion resistance is neglected when the choice of tubing material is made. For example, if a degree of corrosion resistance can be imparted to ordinary steel by the use of a protective coating, and if replacement cost of the article is low, this may be the sensible course.

But where replacement cost is high, or where contamination through corrosion may occur, the wisest, and in the long run the most economical choice of tubing, is a stainless steel of the correct analysis for the conditions of manufacture and service.

Get in touch with Mr. Tubes, your link to B&W, for a detailed comparison of grades suitable for your use and learn how to get more for your money with stainless. *Or write for Bulletin TDC-160 CEP.*

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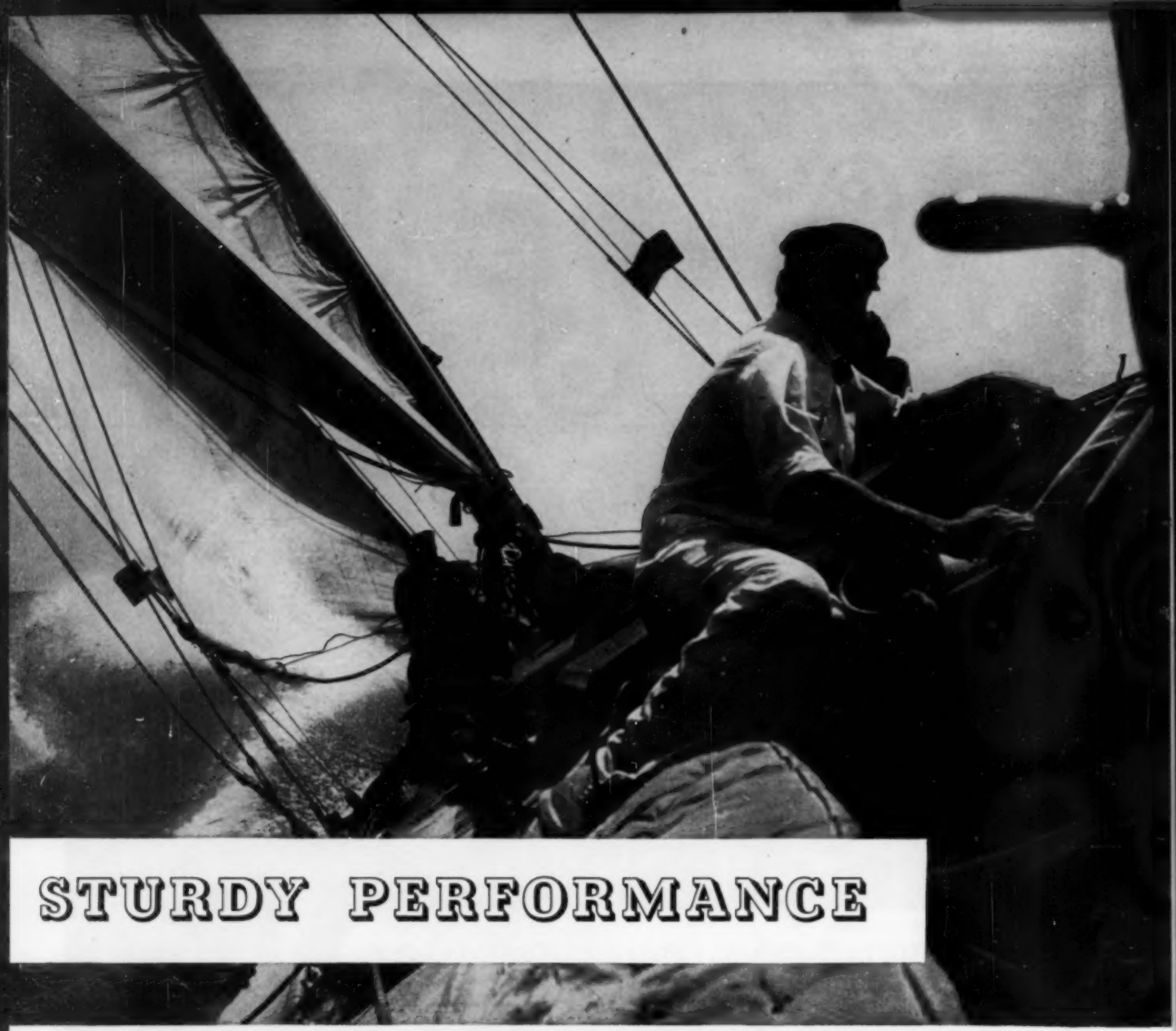

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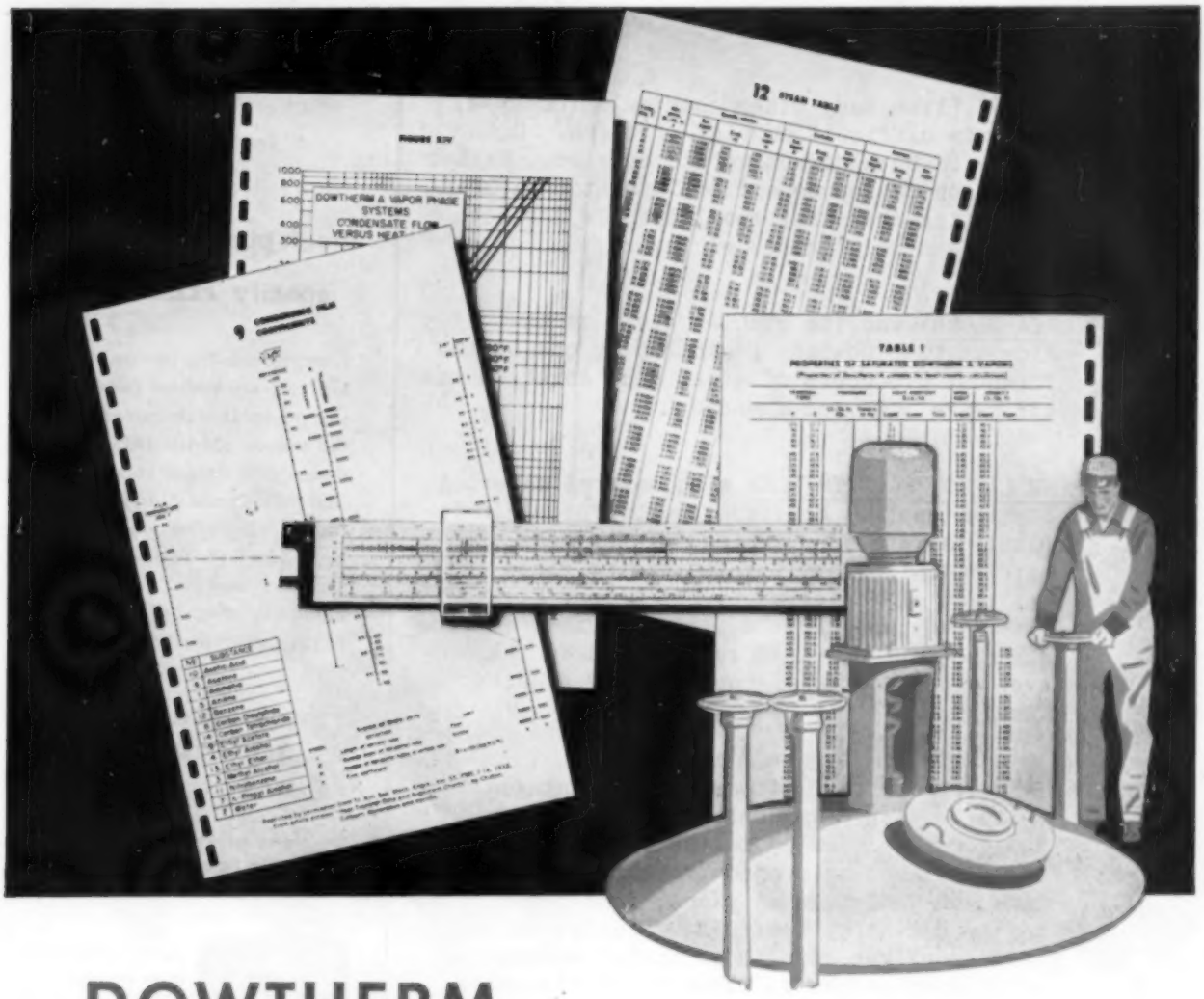

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Many years ago steam provided a giant step in the history of industrial process heating. Today Dowtherm® is providing still another giant step by extending the advantages of vapor-phase heating to much higher temperatures than ever before possible. From noodles to nylon, from paint to plastics—hundreds of industries are processing with greater efficiency and lower cost through Dowtherm heat.

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Pumping Progress Report

FOR HYDRAULIC ENGINEERS

An advertisement prepared by the Aldrich Pump Co. Member of Hydraulic Institute, U.S.A.

UREA PRODUCTION, like many other chemical processes, presents difficult pumping problems. Urea slurry is both corrosive and erosive. Either condition can cause serious operational headaches; together they spell trouble for both design and maintenance engineers.

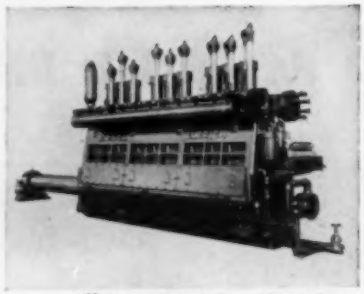
PUMPING UREA SLURRY was the problem given to the Aldrich Pump Company Engineers by one of the foremost producers of urea. Our solution was effective. We recommended...

A 6" STROKE DIRECT FLOW TRIPLEX with several material of construction modifications. Porcelain plungers were used instead of the usual hardened alloy steel. The entire fluid-end was made of Hastelloy B, but Direct Flow Fluid-End construction was maintained to give minimum cost of parts replacement in the event of unavoidable corrosion or erosion damage.

ALDRICH DIRECT FLOW DESIGN offers many advantages to reciprocating pump users. Two right angle turns are eliminated in the fluid-end block. The liquid being pumped travels in a straight line, on a horizontal plane, from the suction to the discharge manifold. Reduced space between valves results in higher volumetric efficiency and extra close valve clearance.

SECTIONALIZED FLUID-ENDS also afford greater economies of maintenance. Valves can be removed for inspection or replacement without special tools or equipment. Individual sections of the fluid-end can be replaced at a fraction of the cost of conventional type fluid-ends.

DATA SHEET 67A illustrates and describes the Aldrich 6" Stroke Direct Flow Pump Series. This Series includes Triplex, Quintuplex, Septuplex and Nonuplex Pumps, ranging in power from 300 to 900 hp. Aldrich Engineers are available to help you solve your tough pumping problems. Address your request to: The Aldrich Pump Company, 20 Gordon Street, Allentown, Pa.



6" Stroke Direct Flow Aldrich Pump.

...for your tough pumping problems specify ALDRICH

Long, trouble-free service life and low cost are assured features of this pump. It is characterized by the unique Aldrich Direct Flow design and rugged construction that have made Aldrich Pumps famous. Modifications can be made to adapt the unit to many types of service. Sectionalized fluid-ends afford fullest economy in maintenance and repair.

TYPICAL CHEMICAL APPLICATIONS FOR ALDRICH PUMPS:

caustic solutions	fatty acids
anhydrous ammonia	nitric acid
amine solution	cobalt solutions
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nickel catalyst	abrasive slurries

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4 *of your units*

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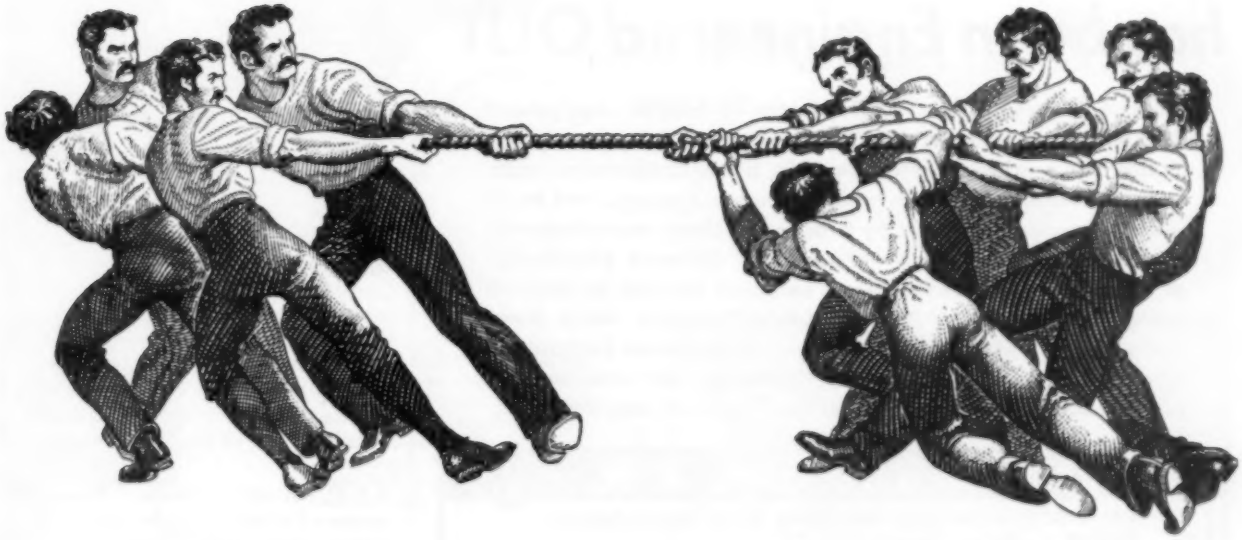
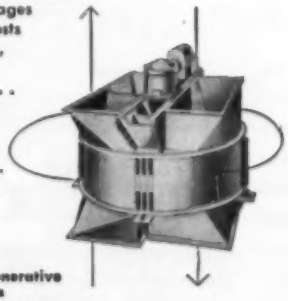


HOW FAST IS "WRITE OFF"?

In most cases, the Ljungstrom installation is quickly written off by increased capacity alone. Write-off time is even less when the other Ljungstrom advantages are considered—saves up to 20% of fuel costs . . . permits more economical furnace design, with no need for convection surfaces . . . burns many fuels you used to throw away . . . results in consistently higher through-put . . . and minimizes slag.

For more complete details on what the Ljungstrom Air Preheater can do for you . . . for an analysis of the heat recovery benefits attainable in fuel burning equipment—call or write The Air Preheater Corporation.

Wherever You Burn Fuel, You Need Ljungstrom



The Ljungstrom operates on the continuous regenerative counterflow principle. The heat transfer surfaces in the rotor act as heat accumulators. As the rotor revolves, the heat is transferred from the waste gases to the incoming cold air.

Recover waste heat, return it to the furnace as combustion air, and you naturally generate higher flame temperatures . . . increase heat-transfer rates—*which means more through-put.*

That's why four of your present processing units can do the work of five *with Ljungstrom Air Preheaters increasing each unit's output as much as 25%.* One eastern refinery increased the continuous capacity of a pipe still from 16,000 to 18,000/20,000 barrels a day—by modernizing and including a Ljungstrom.

The Air Preheater Corporation 60 East 42nd Street, New York 17, N. Y.

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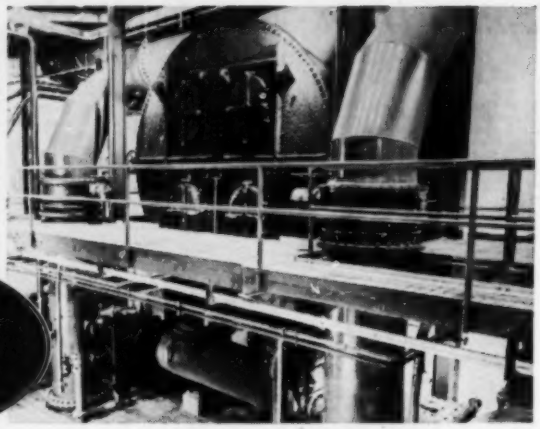
are better



A 33,000 sq. ft. divided flow Conseco Condenser installed in a large power plant. Unit exceeded performance guarantees. Hotwell is full deaerating type, eliminating deaerating heater from feed water cycle.

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No one knows the design weakness of tubular equipment like the men who service it. Conseco Condensers are designed by engineers who work in close cooperation with our maintenance division which rebuilds, repairs, and modernizes condensers made by practically every manufacturer. Through this experience—through our intimate knowledge of where troubles develop—we forestall trouble in Conseco designed equipment. And because troubles have been "engineered out", Conseco Condensers and Heat Exchangers offer you maximum operating efficiency and low maintenance cost. Send for bulletins, stating your requirements.

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ANY DAY
Including Holidays
ANYWHERE
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MARGINAL NOTES

(*Continued from page* 18)

Mr. Killeffer knows how to write and being always close to the chemical scene he knows what to present to encourage the young technologists in the pursuance of their researches and to challenge those men against science who are infected with a malaise of pessimism about our country's future—they *know* famine and annihilation are ahead.

This work contains much statistical data. One statistic was especially interesting to the reviewer because of its contrariety to common acceptance. This is that we consume at our present rate only a little more than half a year of our lives (the statistic is 0.55) from each January 1 to its following December 31. This despite the denunciations on our high-speed living and our burning the candle at both ends!

Only a cursory reading of this work could lead one to believe that Mr. Killeffer attaches undue importance to our material resources, for as he states men, in their strivings toward the higher things of the spirit, have been continually frustrated by material things and their overpowering effects.

H.R.G.

Infrared: A Library of Congress Bibliography. U. S. Department of Commerce, Washington 25, D. C. (1955), 374 pages, $3.00.

Covers all applications of infrared radiation in science, technology, and industry. Has been made available to the public by the Office of Technical Services. Compiled by the Library of Congress, it includes all references to published literature on the subject from 1935 to 1951 which were found by systematic search of available sources.

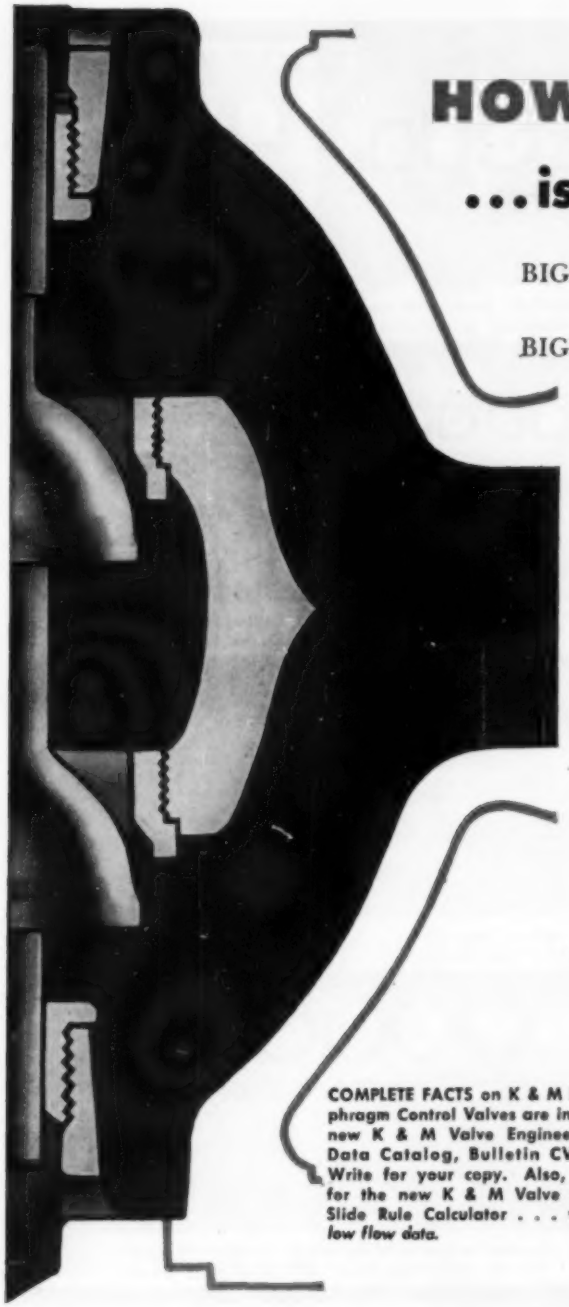
A.E.C. pamphlet, "Nuclear Power Reactors—Volume 2" now available for fifteen cents from Superintendent of Documents, U. S. Government Printing Office.

The work of the Nuclear Power Project Staff of Foster Wheeler Corporation and Pioneer Service & Engineering Co., the pamphlet is a project report submitted to A.E.C. in October, 1953.

Books Received

Instrumental Methods of Chemical Analysis. Galen W. Ewing. McGraw-Hill Book Company, Inc., New York, N. Y. (1954), vii-x+434 pages, $6.50.

Dielectric Materials and Applications. Edited by Arthur B. von Hippel. Published jointly by The Technology Press of M.I.T. and John Wiley & Sons, Inc., New York, N. Y. (1954), vii-xii+433 pages, $17.50.



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BIG enough to pass 500 gpm of cold water through the valve body at a constant drop of one pound pressure.

BIG enough to provide the largest flow coefficient available in a standard six-inch diaphragm control valve.

Body flow passages of all K & M valves, for example, actually average 140% of cross-sectional pipe area. There's more space for fluid to flow . . . smoothly, freely and without turbulence. Frequently a smaller nominal size K & M Valve provides sufficient capacity to satisfy requirements that formerly called for a larger, more expensive valve.

Inner valve open areas, on the other hand, average only 80% of cross-sectional pipe area. Therefore, flow restrictions occur principally across the inner valve . . . where the restriction is controllable throughout the entire range of valve stem travel.

This K & M design often permits lower initial costs . . . always contributes to more precise flow regulation through the K & M Inner Valve.

COMPLETE FACTS on K & M Diaphragm Control Valves are in the new K & M Valve Engineering Data Catalog, Bulletin CV53. Write for your copy. Also, ask for the new K & M Valve Size Slide Rule Calculator . . . with *low flow data.*

C_V COMPARISON TABLE

Valve Size	K & M	Valve B	Valve C
¾"	10.9	8.4	8
1"	17.3	14.9	12
1½"	39.1	33.2	28
2"	61	57	48
2½"	97.7	71.0	72
3"	150	116	100
4"	219	197	165
6"	500	364	360

Based on the maximum C_V at rated travel through the valve body. From manufacturers most recent slide rules or tables.

diaphragm control valves

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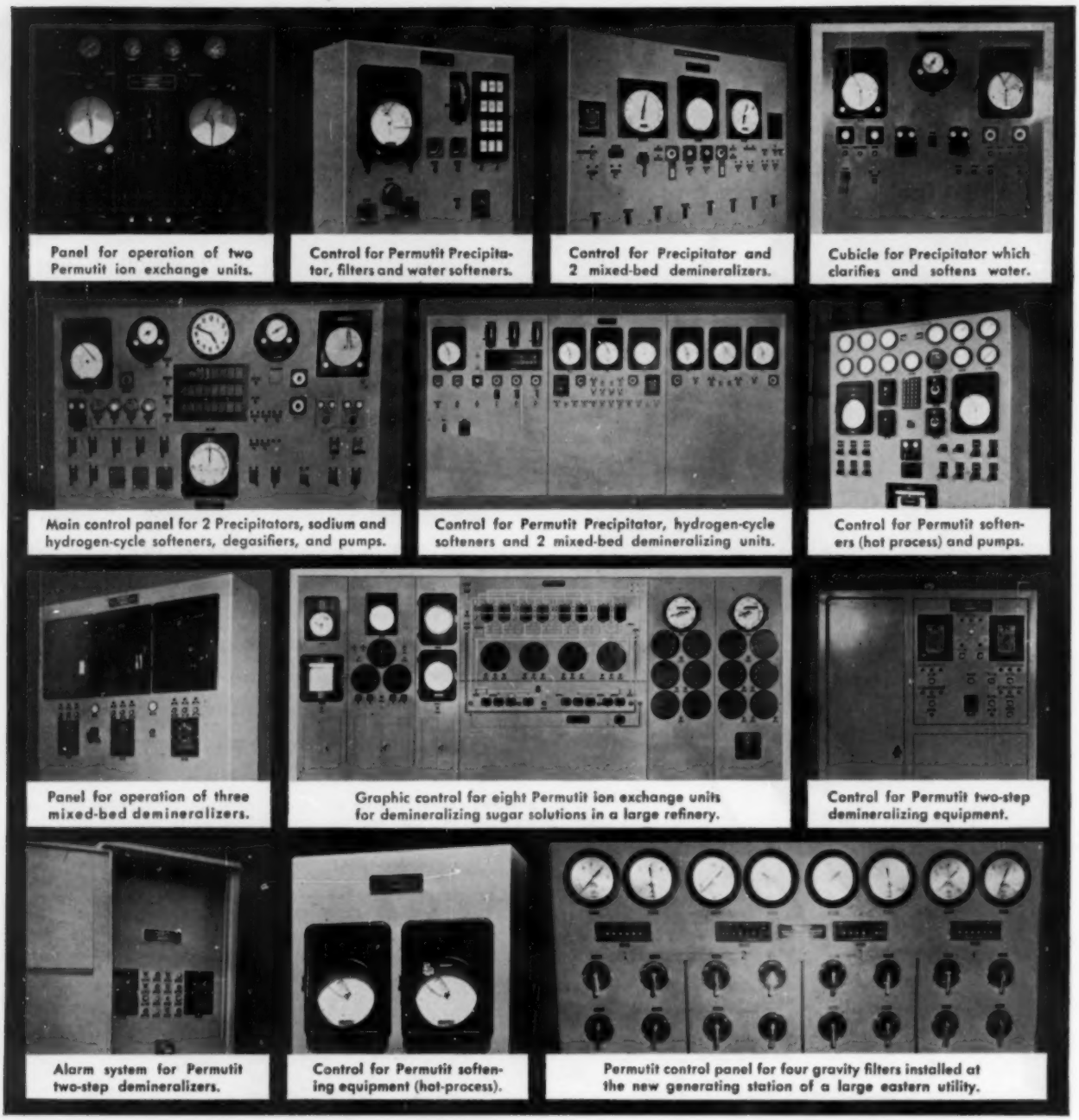

Panel for operation of two Permutit ion exchange units.

Control for Permutit Precipitator, filters and water softeners.

Control for Precipitator and 2 mixed-bed demineralizers.

Cubicle for Precipitator which clarifies and softens water.

Main control panel for 2 Precipitators, sodium and hydrogen-cycle softeners, degasifiers, and pumps.

Control for Permutit Precipitator, hydrogen-cycle softeners and 2 mixed-bed demineralizing units.

Control for Permutit softeners (hot process) and pumps.

Panel for operation of three mixed-bed demineralizers.

Graphic control for eight Permutit ion exchange units for demineralizing sugar solutions in a large refinery.

Control for Permutit two-step demineralizing equipment.

Alarm system for Permutit two-step demineralizers.

Control for Permutit softening equipment (hot-process).

Permutit control panel for four gravity filters installed at the new generating station of a large eastern utility.

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Life might be simpler if we "farmed out" our control cubicles and instrument panels . . . but we like to build *every* major component of a PERMUTIT water-conditioning or ion exchange system . . . so that we know it will do its specific job properly.

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85 to 100% of your corrosion-resistant piping needs now available from 1 source

There is no single material for chemical piping that can handle all corrosive fluids . . . and do it economically. To meet all needs, American Hard Rubber Company has developed and refined no less than eight basic types of corrosion-resistant rubber and plastic pipe and tubing...plus a wide variety of fittings, valves, pumps, and other equipment for assembling completely protected chemical systems. ACE distributors and field engineers will be happy to make recommendations . . . call ACE first.

WHICH PIPE SHOULD YOU USE...		WHERE...WHEN?
ACE-ITE Threaded Pipe ½" to 6"	General purpose rubber-plastic blend. Tough, impact resistant. Odorless, tasteless. Economical.	Handles most common chemicals to 170°F. except a few strong acids and certain organic solvents.
RUBBER-LINED STEEL Flanged Pipe 1½" to 24" and up	Strength and pressures of steel plus resistance of hard rubber. Soft rubber interlayer aids shock resistance.	Finest resistance to alkalis, most inorganic acids, many organic acids, all salts. Ideal for bleaches.
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ACE RIVICLOR Threaded Pipe ½" to 4"	Rigid plastic, special PVC. Outstanding aging characteristics. Good cold impact strength.	Lies between Saran and Parian. Not affected by most inorganic acids and alkalis. Good for many organics also.
ACE PARIAN Threaded Pipe ½" to 2"	Odorless, tasteless, rigid polyethylene. Not strongest plastic, but best for sub-zero uses.	Best resistance of any plastic at room temp. except to acetic acid. Good for alkalis, acids, many organics.
ACE HARD RUBBER Threaded Pipe ¼" to 8" Flanged Pipe 1½" to 8"	The oldest, still tops. Widest range of fittings of any rigid non-metallic pipe.	Extreme resistance to alkalis, most inorganic acids, many organic acids, all salts. Ideal for chlorine, fluorine.
ACE SARAN Threaded Pipe ½" to 4" Tubing ⅛" to 1¼"	Odorless, tasteless, general-purpose rigid pipe and semi-flexible tubing. High pressures.	Excellent . . . not affected by most inorganic acids and alkalis. High resistance to most organics.
ACE-FLEX Flexible Tubing ⅛" to 1¼"	General-purpose transparent flexible tubing. Non-toxic, odorless, tasteless. Can steam-sterilize.	Very good resistance to most inorganic acids and alkalis. Resists many organics at room temperature.

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LUMMUS

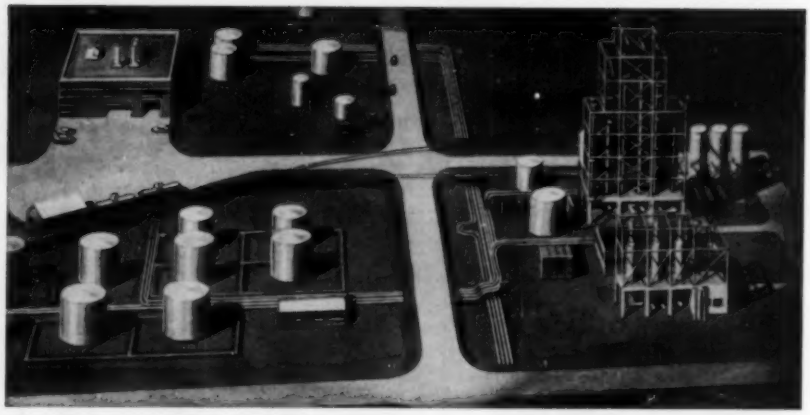
DESIGNING ENGINEERS AND CONSTRUCTORS FOR THE PETROLEUM AND CHEMICAL INDUSTRIES

LUMMUS TO BUILD AIR REDUCTION CHEMICAL'S VINYL ACETATE PLANT AT CALVERT CITY, KENTUCKY

Lummus-Built Plant To Come On Stream In Early 1956

The 30,000,000 lb. per year vinyl acetate plant which The Lummus Company is engineering and constructing for Air Reduction Chemical Company, a division of Air Reduction Company, Inc., is a good example of how industry can set up an integrated plant in a strategic location, and insure maximum returns for its capital investment. The plant's attractive location at Calvert City, Kentucky has all the benefits of readily available power, natural gas, water transportation, and a host of related chemical products.

This $3,000,000 installation scheduled for completion early in 1956, is adjacent to the calcium carbide and acetylene plant of Air Reduction's National Carbide Division, and will receive pipeline acetylene from it. The new vinyl acetate plant will be a key development in Air Reduction's chemical expansion which begins with basic raw materials and ends with a variety of products having important commercial and industrial uses.



Vinyl acetate goes principally into polyvinyl acetate emulsions, used in adhesives, latex paints and textile finishes, and polyvinyl alcohol used for adhesives and textile finishes.

At Calvert City, in addition to this new Air Reduction plant, Lummus is also building a $6,000,000 high pressure acetylene derivatives plant for General Aniline & Film Corporation. What better example could be given to show that Lummus is ready, willing and able to design, engineer and construct your next chemical plant.

The Lummus Company, 385 Madison Avenue, New York 17, N. Y. **Engineering & Sales Offices:** New York, Houston, Montreal, London, Paris, The Hague, Bombay. **Sales Offices:** Chicago, Caracas. **Heat Exchanger Plant:** Honesdale, Pa. **Fabricated Piping Plant:** East Chicago, Indiana.

CONTROLLED-VOLUME PUMPING with

CEP trends / CHEMICAL MERGERS

Not for the past twenty years or more has the chemical industry seen such a rash of mergers, acquisitions and combinations as it has in the last year or so. There is no sign that this trend is slowing down. Various sizeable deals are at least in the talking stage, though many may never come through.

Generally speaking, in the recent past chemical giants have grown chiefly from within, expanding through research—Dow Chemical, Du Pont and Union Carbide being examples of this policy. But now there is a "new look" in the industry. Typical is Monsanto, a company without a major acquisition for many years, just merged with Lion Oil (subject to stockholder approval). If approved, Lion will become a division of Monsanto, bring its oil facilitites to Monsanto's petrochemical facilities, its ammonia and derivatives to Monsanto's fertilizer production. The merger will make Monsanto a $550 million company.

Many Reasons

There are many reasons for this "new look" in chemical expansion. For one thing, the Republican Administration has created a favorable climate for business, has made business leaders feel they can go ahead without legal battles. Another factor is abundant capital, the ease of raising money. Prominent is the desire to secure sources of raw materials, expand the company's market picture, bring new and diversified experience into the firm. Diversificatiton is certainly a factor, as companies become cautious at having all eggs in one basket. Then there are the various individual reasons, ranging from "empire building" to the simple desire to round out a line, fill a gap.

Outstanding among examples of empire building is the Olin-Mathieson combination. Nothing of the magnitude and scope of this structure has been seen since the days of the 1920's when Allied Chemical was built from four or five firms, and the 1930's when American Cyanamid was created by merger.

Starting with a small, lethargic alkali maker, Thomas Nichols took Mathieson, merged it with two important fertilizer producers, went into petrochemicals. Drug-maker Squibb was next merged, making Mathieson a $250 million concern overnight. Then Olin Industries and Mathieson combined, making a new giant with total assets of over $550 million, which then absorbed Blockson Chemical, maker of phosphates, with around $30 million annual sales. Latest move—purchase of the Brown Paper Mill Co. at a price stated to be around $90 million. Thus the giant now, or at least by the year end, will have assets of around $750 million and be the third largest firm in the chemical process field. A proposed new venture is the building of an aluminum plant.

Dividing Line Broken

The dividing line between strictly chemical business and other business seems to have broken down. All sorts of diverse firms, such as Food Machinery, Minnesota Mining and Borden Co. (dairy products) are active in the chemical business.

W. R. Grace & Co. already a shipping, trading and banking empire, has long had its eye on the lush pastures of chemistry. It acquired Davison Chemical Co.—fertilizers, oil refining catalysts and other chemicals with annual sales of $42 million, and Dewey & Almy—rubber goods and packaging materials with annual sales of about $35 million. The new Grace Chemical Co. has recently completed a $20 million ammonia plant in the south. Over all last year Grace had total chemical sales of $130 million, or about double its steamship revenues. This contrasted to chemical sales of only $29 million in 1952.

More Logical

A third, more logical type of expansion by acquisitions has been the program of Hooker Electrochemical. Hooker, one of the smaller firms in the business, boosted its own sales to $44 million last year, up from $27 million in 1950. Building on a foundation of alkalis, Hooker upgraded its products by turning the low profit margin alkalis into a wide range of chemical specialties, branching out from there. Recently developing a number of interesting new plastics it merged with Durez Plastics & Chemical Co., a maker of phenolic resins with a ready made sales, technical and research force in the plastics field. Following this, purchase of Niagara Alkali will bring Hooker's total assets to around $100 million.

There have been many smaller acquisitions lately, mostly big companies absorbing small ones. Allied taking over Mutual Chemical (chrome products); Pfizer buying J. B. Roerig for wider, efficient pharmaceutical distribution; Warner Hudnut merging with Lambert Co. to create $100 million annual sales Warner Lambert Co.; Koppers taking over American Aniline Products; Borden, long in plastics, widening its interests in that field by buying American Monomer and Monomer-Polymer, Inc.

More Combinations

Whether the merger trend will continue or has passed its peak cannot be told at the moment, but it seems that more combinations will take place, providing cheapest, quickest way to new raw materials, markets, experience. Chief executives of many moderate sized firms freely admit they are looking for good buys.

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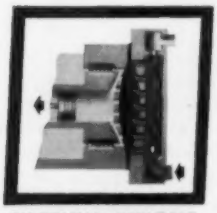
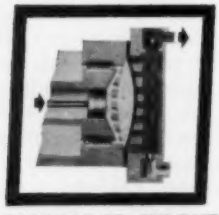


SUCTION STROKE



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WRITE FOR BULLETIN 440 *with typical applications, flow charts, description and specifications of models of various capacities and constructions. Inquiry Data Sheet included from which we can make specific engineering recommendation for your processing requirement. Write Lapp Insulator Co., Inc., Process Equipment Division, 501 Wilton Street, Le Roy, N. Y.*

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CEP what's in this issue...

you may be interested in—

CHEMICAL MERGERS - (p. 29) - What do they mean and will they ultimately benefit the engineering potential of firms involved? Get answers in TRENDS . . .

We Are Proud to Present:

PROCESS CONTROL ROUNDUP - (pages 343 thru 360) - In four articles we believe you will find an outstanding assessment of both the present status of process plant control, as well as bases upon which you can start augmenting your present systems - planning the new . . .

- - ROUNDTABLE - (p. 343) - reports opinions and experiences of men in charge of control over five major petrochemical & petroleum refining works in Texas . . .

- - CONTINUOUS INFRARED ANALYSIS - (p. 348) - of sidestream off large butadiene plant distillation column enabled improved control of unit. Detailed experience account should serve as guide for other applications.

- - FREQUENCY RESPONSE - (p. 353) - as a new tool for the design of process control systems - is described in easy-to-understand language in the first of two articles to appear on this subject . . .

- - GUIDE TO CONTINUOUS STREAM ANALYSIS - (p. 357) - cites what one can do with composition information - in contrast to the environmental type of information available in the days prior to having access to these instruments . . .

SEPARATING PETROCHEMICAL MIXTURES - (p. 361) - Many of us recall the days not so long ago when there was much speculation among experts as to how the first commercial plants would achieve economic separation of the complex mixtures of compounds made by oxidation of hydrocarbons . . . Well, in this article, CELANESE tells how they've been doing it!

MAKING BIGGER PARTICLES OUT OF SMALLER ONES - (p. 364) - is getting to be a science. At least, the work chemical engineers have been doing on AGGLOMERATION is tending to improve the predictability of results. Reported is application to iron ore concentrates . . .

HOW FLUIDIZATION MADE POSSIBLE ECONOMIC RECOVERY OF SULFUR FROM LOW GRADE ORE - (p. 369) - is given a detailed experience-report by DORR-OLIVER engineers, regarding Anaconda's Yerington Plant . . . The data in this paper may give you ideas about other materials . . .

EXTRACTION OF SOYBEANS - (p. 372) - studies explode old concepts! Concentration of oil in extracting solvent or miscella has no effect on extraction of oil from bean flakes! This and other surprising findings reported . . .

DUST OFF YOUR THINKING ABOUT HOW TO TRAIN TOMORROW'S CHEM. E's - (p. 379) - Some, at least, are going to have to be a good deal more scientifically-grounded than "me or thee" . . . Concept described in article goes "on stream" this fall at the University of Michigan . . .

$$$ - AUDITOR'S REPORT - (p. 382) - of the Institute, annual C.E.P. feature.

UNUSUAL OPPORTUNITY TO FAMILIARIZE ONESELF AS TO MANAGERIAL ASPECTS - (p. 33) - coming up at one meeting you can hardly justify affording to miss - LAKE PLACID! In our final pre-meeting article, we have attempted to give you a rather detailed analysis of the highlights to expect . . .

EXPECT TO BE HEAT TREATING ANY VESSELS A COUPLE OF HUNDRED FEET UP IN THE SKY? - (p. 36) - Unusual achievement by fabricator for Sun Oil paves way for other uses of technique.

WHAT SOME PUMP USERS THINK - (p. 38) - about standardization, packingless pumps, and rating data on viscous fluids.

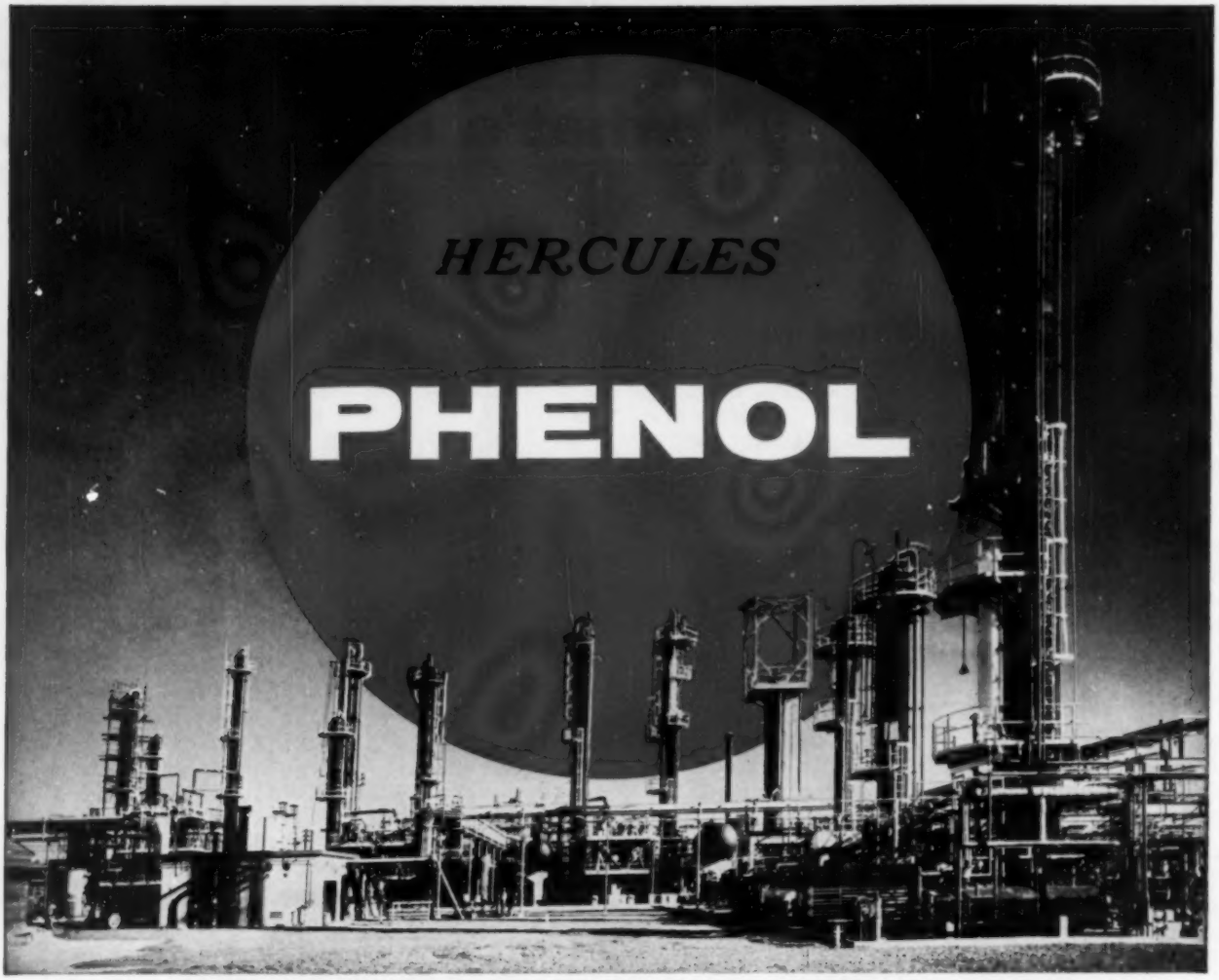
SELECTION GUIDE FOR ORGANIC COATINGS - (p. 40) - for corrosion resistant application . . . First of series of reference sheets based on extensive actual experience of author . . .

PROFESSORS' WORKSHOP - (p. 64) - an annual event - heard reports on what has been accomplished, where to go from here . . .

LOOK INTO LOS ALAMOS - (p. 83) - Certain restrictions lifted, photos permitted . . .

NEWS & NOTES - (p. 92) - keeps you up to date on what's happening in A.I.Ch.E.

-- J. B. M.



Hercules Powder Company plant at Gibbstown, New Jersey—largest facilities for the production of U.S.P. phenol on the eastern seaboard.

ANOTHER EXAMPLE OF "PARTNERSHIP IN PETROCHEMISTRY"

Many chemical manufacturers who have expanded their activities into petrochemicals, such as Hercules Powder Company, have found it advantageous to have The M. W. Kellogg Company work with them on their process or plant engineering problems.

One reason for this is M. W. Kellogg's 50 years of experience on comparable problems in petroleum refineries, and its more recent background in petrochemical plants. The latter includes ammonia facilities for Shell Chemical Company and Standard Oil Company of Ohio, ethylene plants for Imperial Chemical Industries Ltd., and the phenol-from-cumene project for B. A. Shawinigan Company.

The M. W. Kellogg Company can assume responsibility at any point. In Hercules' case, engineers of both companies collaborated in engineering the process and the mechanical design of this phenol-from-cumene plant. Hercules supplied the process for producing phenol-from-cumene. Kellogg supplied the process used for making the cumene feed. Kellogg erected the process units.

M. W. Kellogg would like to work in partnership with *you*, and invites you to review the facilities it can provide in keeping your initial investment and pay-out time to a minimum.

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PETROCHEMICAL PROCESSES AND PLANTS

CHEMICAL PROCESS DIVISION

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CEP

opinion and comment

A TWO-WAY STREET SHOULD BE JUST THAT

A frequent complaint of our day is that so many seem willing to transfer responsibility for taking definite positions on issues to others "more eminently qualified."

Speaking recently before an audience of chemical engineers, Professor Rushton said that in the field of education we don't seem to have as many strongly assertive people as we used to have. "Remember your college days?" he asked. "You can all probably recall several real characters who did put across attitudes—and you got something from them. At least, that's all you remember about them now."

Is it that we have come today to feel that the safest position with respect to exhibiting attitudes towards policy decisions is just "no comment" or "anonymous"?

We live in a social order which requires continual progress. Certainly no profession has contributed more to this progress in recent decades than has ours. But as we have left the era of great individual founders and inventors, and come into an era in which teams armed with great facilities account for major developments, have we as individuals begun to feel that we shouldn't sit down and, while in the mood, jot down a comment or express a different idea or a thought that befits an occasion—without worrying about hurting some fellow's feelings?

We have in recent months published a series of articles in C.E.P. dealing with various facets of human relations among and affecting professional men. Likewise you and we should feel free to comment creatively in print on issues of the day, in a manner stimulating and without offense to others of good intention.

What brings this comment forth is that we don't receive enough Letters to the Editor. At least, we don't seem to get as many as the issues at stake would seemingly deserve. Certainly, there is no lack of interest. Face to face, we get a great deal of comment and advice. But ask the same people to put it in writing and what happens—usually little response. Granted, people are preoccupied these days and doubtless feel that once their sentiments get across enough is said.

What this all comes down to is—let's have more letters from *you*.

GREAT CHANGES

We recently attended the launching of the "Sea Wolf." Major impression was that of a pressure vessel—some 330 × 27 ft., lying on its side, with a strange contraption strung along its upper edge. As a device sired through the urgency of national emergency, it will doubtless serve as a floating laboratory of benefit to nuclear power reactor development.

Back from the launching, we were pleased to see advance copies of papers for presentation at the Geneva atomic sessions. These appear to represent major changes in declassification policy, which is good. We're of the opinion that once given enough information, the chemical engineers will simplify and economize systems now thought too costly and complex for open competition.

J.B.M.

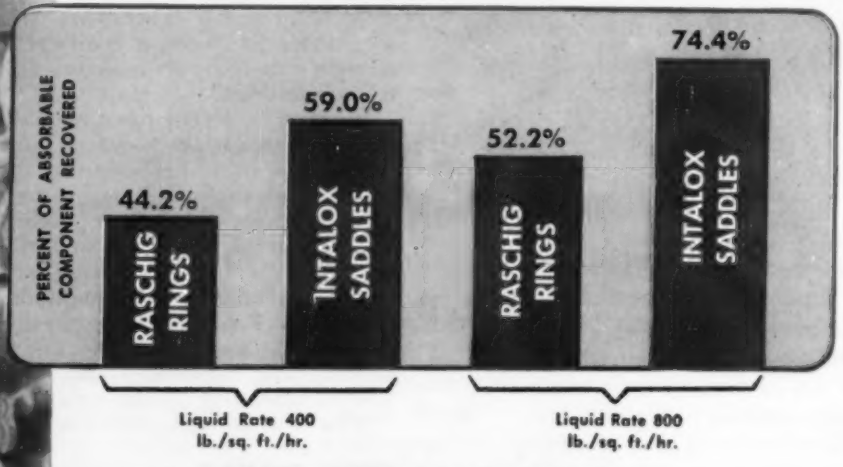
HOW TO INCREASE ABSORBABLE COMPONENT RECOVERED WITHOUT INCREASING HEIGHT OF PACKED COLUMN

We alternately packed a pilot plant tower first with 10′ of Raschig Rings and then with 10′ of Intalox Saddles. Using identical gas and liquid rates and the same gas composition, absorption data for the two packings were obtained. One swallow, of course, doesn't make a summer, so we repeated the test again and again to be sure our original conclusions were justified.

If you're facing the problem of recovering a higher percentage of absorbable component from your present absorption towers, *it appears obvious* that you can increase the absorption level as much as 30% or more by replacing Raschig rings with Intalox Saddles. And without changing either liquid or gas rates!

Turning the problem around — if you're planning new tower construction for absorption operations — it appears *equally obvious* that tower height can be substantially less If Intalox Saddles are specified for the tower filling.

Actually, the increase in absorption level through using Intalox Saddles can be substantially greater than the test data indicates — for Intalox Saddles permit higher liquid and gas rates to be carried before flooding occurs.



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Gives full technical data and specifications on Intalox Saddles, including comparative charts showing relative pressure drops, flooding limits, gas pumping costs, etc.

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Exclusive CEP Field Report—
Place: Houston, Texas

Draffen, Hart, Alexander, and Anderson recall amusing experiences.

How do men responsible for control of huge chemical plants and refineries typical of the Southwest look upon trends developing in process control technology? Answer to this and other timely questions is brought out in C.E.P.'s . . .

ROUND TABLE ON PROCESS CONTROL

C.E.P. Editor: We would like to determine at this meeting what direction the application of process control developments is taking with respect to your petrochemical and petroleum refining plants, and where the special skills of the chemical engineer fit into this picture. Some of us feel that the development of process control devices and applications appear at this stage to be confusing. I have heard some instrument manufacturers remark that the development of devices has outpaced the development of applications for such devices.

Alexander: I think that part of our problem concerns the process engineer who is going to design a plant. He must recognize what he is up against in providing controls in the way of instrumentation. He must have a good knowledge of control technology–possibly 75 or 80% as much as the instrumentation specialist. He must have a general broad understanding of what is available and how such information can be applied before he can sit down with the instrument man. Perhaps we can recommend some aids for him.

Role of Chemical Engineers

Alexander: - Our process engineers at Monsanto certainly don't select the instruments–they only select the type of control–they know what they want to control and what their control points are. For example, in a fractionator they've got to know if they want to put a temperature controller on, what point in the column offers the greatest differential in temperature measurement and gives the greatest response on the instrument and so on. But they've got to have some understanding of that

Those who took part . . .

Moderator *

Wayne E. Alexander, asst. director, Engineering, Plastics Div., Monsanto Chemical Company, Texas City, Texas.

M. K. Anderson, instrumentation project engineer, Engineering Dept., Carbide & Carbon Chemicals Company, Texas City, Texas.

Porter Hart, superintendent of Instrumentation, Dow Chemical Company, Freeport, Texas.

J. F. Draffen, group leader, Process Control Group, Plastics Division, Monsanto Chemical Company, Texas City.

J. L. Walker, control specialist, Refiners Technical Service Division, Humble Oil & Refining Co., Baytown, Texas.

H. D. Grove, instrumentation group leader, Petrochemical Development Group, American Oil Co., Texas City.

R. F. Wall, analytical control group leader, Research Dept., Plastics Division, Monsanto Chemical Company, Texas City.

* C.E.P.'s thanks are due Wayne Alexander for making all pre-meeting local arrangements with participants, plus serving as Moderator.

concept or they can't design the column in the first place.

The process engineer doesn't say that it is going to be a Brown or Foxboro Model or so and so. Our instrument people still do that.

Grove (Amoco): The way we take care of the problem at American Oil Company for pilot plants is by having mechanical engineers who work directly with our chemical engineers. The chemical engineers design the pilot plants and also figure out what variables will or will not be automatically controlled. The mechanical and chemical engineers then confer and work closely together to produce a final complete design for the pilot units. The mechanical engineer usually follows the actual construction of the pilot unit and installation of instruments. He is called upon also to solve any serious problems occurring with the instruments. Our engineering department is so organized that the mechanical engineers assigned to pilot plant construction and maintenance can obtain the advice of instrument specialists. The staff of instrument specialists working for our engineering department is consulted in regard to knotty problems and also about new equipment.

An instrument committee composed of mechanical and chemical engineers and instrument specialists has been set up at our Texas City refinery. This committee, meeting approximately every two months, is usually presented with problems requiring the application of instruments in an unusual manner. Ideas regarding new types of instruments and new instrument applications received from the technical and nontechnical staff are reviewed by this committee.

Draffen (Monsanto): When the process engineer decides that he wants to control a temperature by adjusting a valve in some stream, he is designing an automatic control system. How he picks the control point and where he puts the valves may have a lot more to do than may appear with how well the plant is controlled.

Keeping Up

Draffen (Monsanto): In the matter of the effort by chemical engineers to keep up with new instruments and new equipment, it has always been my opinion that it's not so much the instruments you use, but how you use them that is important to chemical engineering. I would think that keeping up with new developments is a job for the instrument engineer.

Alexander: Part of the chemical engineer's control problem can be solved through his knowing the most up-to-date applications information on things available to him. Certainly there has been a lot of change in recent years.

Hart (Dow): I think that what Jack [Draffen] was just talking about sort of reminds one of the plant operator and the process engineer who agree that a temperature should be taken on a certain tray. Then, things don't work out and the only way you can fix things up is to go at night when they're not there and take it down where it should be. Then the system lines up properly and you hope that they [management] don't know about what happened until six months later!

Walker (Humble): I think at times that chemical engineers are unnecessarily reluctant to go to talk with specialists in process instrumentation.

Alexander: They are.

Walker (Humble): A process design man is going to put into the process what he knows about instrumentation and only in special cases is he going to go to somebody else to ask for help. We need to educate the chemical engineer in general as much as we can.

Draffen (Monsanto): It is going to take a lot of missionary work.

Alexander: If we could spark them through the right kind of magazine articles, it might help.

Hart (Dow): I think the trouble with many articles along the line we're speaking of, is that they start out in the middle, and that is bad. You're fortunate if you have enough background to be able to follow along.

Alexander: In the case of process engineers, they may not know enough of fundamental instrumentation principles.

Grove (Amoco): I think it is necessary to read current listings of all new instrument developments. Several of the instrument manufacturers now have available a variable temperature-range controller. A unit can be plugged in that will allow variation of the range of a temperature recorder controller over wide ranges. Installation of an instrument of this kind would eliminate the use of range change kits. I would personally like to know a good deal more about each new development.

Walker (Humble): My company has a rather large staff of instrumentation experts, but I think the man in the field using the instruments from day to day has to develop certain ideas–about things in direct application. It's different from what you can design on a drawing board. You can't possibly design all these things. You have to find them out sometimes from the experience of others.

How Soon Automation?

Porter Hart (Dow): On the subject of devices outpacing applications, in our type of industry we of course hear many appeals that data-handling equipment is good and should be used in some special places. However, it is expensive. Furthermore, it is my feeling at the present time that in the chemical field of process control our money is better spent on the analysis of stream products–putting on plant stream the basic methods in use presently in our plant laboratories. Then we will be better prepared to go into the more advanced data handling that is being developed rapidly for the chemical process and other fields.

C.E.P. Editor: Would you explain data handling?

Hart (Dow): What I'm referring to are the data-handling machines and computers many firms are coming out with and expecting to put right on stream in plant processes. First we will have to learn to use simple computers before we can learn to use complicated ones—to use the simple computers where there are two components to be calculated out to a given net result. It is true that the operator of a chemical plant cannot look at temperature and look at pressure and go to look at charts—it's confusing. So we have to simplify it for him by computing these two values together that come out as a percent on a chart.

C.E.P. Editor: You want to see more information about the variables in the process streams rather than see effort devoted to ways of correlating large amounts of such information which as yet we really don't have?

Hart (Dow): Yes.

Grove (Amoco): There has been a good deal of argument about central-control and data-processing systems. Complete refineries are being designed now in which the process variables are recorded and processed by calculating machines. The process flows, temperatures, pressures, etc., can be recorded, and the product yields calculated and transmitted to the central office entirely automatically. This type of system would eliminate the necessity of manually recording the instrument readings at intervals, but what are the advantages of having the instrument manually read? The operators are required to keep in close touch with the process variables if manual readings are taken. However, if manual instrument readings are not required because of use of a data-processing system, the personnel would have more time for other important duties. Maybe you can reduce the operating personnel by use of a data-processing system, but the maintenance requirements for the instrumentation system would probably increase. Discussions of the pros and cons of setting up such a system will in the future unfold much information that will be important to watch.

Alexander: I think this bears on the problem involving infrared analyses where the hope has been expressed to tie in with a computer and achieve automatic control. This seemingly cannot be done at this time. It still requires some human element of judgment. I think this is an example perhaps of using a simple computer. We feel that we don't know enough yet about how to operate some of the equipment to get all the variables under control in one computer.

Suppose an instrument does go off its correct functioning. It's not the operator's opinion—the instrument says

computer, you would need some elabo- **Anderson** (Carbide): Do you think equipment for benzene-toluene separa-

it's on grade, but it actually isn't. Then you are in trouble. You might contaminate a whole tankful of material with off-grade that requires rerun. To achieve complete automation of that type, you must replace the element of human judgment with further devices to tell on each other if they go bad.

Anderson (Carbide): I'm going to support what Porter Hart said. In other words, I think we ought to get better data to put into these machines. We are still in an analytical era–the instrumentation period.

Alexander: I think there is more to it today than just a smart operator. We even have a lot to learn about the reliability of analytical devices. Some really must be developed further before we dare tie them to something else.

Hart (Dow): We can afford to spend $100,000 on instrumentation to make a full-time man twice as productive. That's quite a figure, a lot of money, but it's a figure no one has yet challenged.

Alexander: I think you're conservative with your figures.

Hart (Dow): Getting back to the subject of automation, we have centralized control rooms now, and many plants are related to one another productionwise in the larger chemical industries. One of our next moves will be to have control stations where we will do away with the units of centralized control room and have a control station where possibly five plants are controlled out of that control station and there you have all the information relating to the operation of those five plants in that one place. You can afford to do a much better job for you know how the plants affect one another and you can correct conditions much more readily without having to depend upon other factors of communication. I think that step is not too far away–control stations and not control rooms.

Alexander: I think the petroleum industry may have a greater interest in flashing data to New York than would the chemical industry. The former is out for volume on generally standardized products whereas we are working in smaller lots against rigid chemical and physical specifications.

C.E.P. Editor: I'd like to ask Jack Draffen whether he thinks the refineries may be proving grounds for the chemical industry in developing certain aspects of automatic control?

Draffen (Monsanto): Well, I don't think that automatic control is any different in a refinery from what it is in chemical production. Of course, we use some different types of equipment so that data on equipment might not apply, but control techniques should be transmitted directly. In order to get five plants together for over-all control, you would have to change your method of presenting data, Porter. You can't merely extend recorders on a longer panel from the way we do it now—it would get your panel board a mile long.

Draffen and Hart Dubious?

Hart (Dow): That's right. You would eventually have a problem here in that you have to arrive at some way to enable a man to look at 200 controls at once.

Alexander: Right now the man sitting in the cockpit of an airplane is doing that; it can be done.

Awaiting Mathematics

Draffen (Monsanto): I heartily agree with Porter but for different reasons. There are groups pushing computer control and the completely automatic plant, but I don't think that it is feasible at the present time. We don't know enough about how our automatic controls work. My own conviction is that before we can let a computer set all the individual controls determining the operation of a plant, we must first be able to put the mathematical equations for the plant into the computer, and we are a long way from being able to do that.

C.E.P. Editor: There are groups of mathematicians working on the application of computers to process control.

Draffen (Monsanto): There are some groups in this country trying to work out the dynamics of plant controls. My opinion is, however, that the chemical engineering profession has in general been ignoring that particular development. Basically, the theoretical treatment of the automatic control of chemical processing is chemical engineering. It isn't so much the instruments that determine the control as it is the process, and to predict how the process will operate under automatic control, it is necessary to make not only ordinary heat and material balances but also dynamic balances—which essentially means being able to write differential equations for the plant.

Hart (Dow): The chemical process has a nervous system. How do we know what the process likes? We instrumentize our plants as fully as we know how, and when they go on stream some of the things we "think" we least need to do are what the process likes. I don't know if the mathematician can develop these equations before the plant is in operation, but we certainly can get them after the plant is in operation.

process control

Draffen (Monsanto): The trouble, Porter, is that after you build the plant the opportunity for making big savings on process equipment is gone.

Hart (Dow): That's right.

Alexander: Chemical engineers have got to recognize some of these things –it's part of their work. They just can't leave it to the specialist—there are too few of them in the first place; they just can't cover the waterfront.

Hart (Dow): It won't be easy. I have given a few of these problems to college mathematicians; they haven't got very far. Some simple distillation problems, yes. They say—"Sure we can compute the contents of these things" —and then they give up in about a half hour.

Draffen (Monsanto): It isn't easy to do this—distillation problems are about the most difficult you can attack.

Alexander: The mathematicians have, I think, missed out on the dynamics of the distillation process.

Wall (Monsanto): In processes like that, the so-called constants aren't exactly constant. To control such with a

computer, you would need some elaborate, complicated system to feed in all your primary information—surface tensions, chemical composition changes, etc. for example.

Alexander: I happened years ago to have contact with a mathematical consultant who did devise some rather ingenious ways through mathematical approaches to handle varying blends of charge stocks of petroleum distillation systems and to apply some form of automatic control. I think the things we are talking about here are beyond what he did, however. I just wanted to throw that in as an example of what mathematicians can do.

Draffen (Monsanto): We have been talking about mathematically solving control problems–setting up the mathematical equations which predict how the control will work before the plant is built. That's an exceedingly difficult thing to do. To do it all, requires that the problem be simplified tremendously, and it is not obvious what simplifying assumptions can be made ahead of time. I think the solution of this problem is going to take a great deal of both mathematical and experimental work. We need to gather considerable data and attempt to correlate them.

Equipment Characteristics

C.E.P. Editor: You mean experiments with operating full-scale plants?

Draffen (Monsanto): Yes. Also much fundamental research work needs to be done on the dynamics of process equipment–work that the colleges could do if they had the equipment.

C.E.P. Editor: Mostly continuous operating equipment?

Draffen (Monsanto): In general, yes.

Anderson (Carbide): Do you think these data could be gathered in some useful way on a ratio basis? For instance, if one knows what the characteristics of an ordinary extractor would be—then someone comes along with a special extractor—if we had some relationship or ratio constants, that would be a help.

Draffen (Monsanto): To some degree, yes. He would attempt to correlate test results by the use of dimensionless ratios. Also, if process equipment were more standardized, it might be possible to gather a file of data on commonly used pieces of equipment. Then when we wanted to use this equipment we could pull the information out of the file.

C.E.P. Editor: Are you trying to do this now?

Draffen (Monsanto): Yes, as we have the opportunity. We have not made many measurements solely for the purpose of collecting data. We have measured what we needed to solve–one particular problem at a particular time.

C.E.P. Editor: What would be typical of what you have done?

Draffen (Monsanto): So far, mostly the instruments themselves–they are fairly well standardized so that it is possible to measure the dynamics of a controller, put the results on file, and use them later. Unfortunately, the instrument is not usually the major factor determining the way the control system acts.

Alexander: I'm inclined to feel that we can't expect to standardize sufficiently some of these things. The science or art of chemical engineering has after all been based on empirical information. It is one thing to develop correlations in the design of a piece of equipment for benzene-toluene separation, but when you use something other than benzene, the same unit doesn't seem to act the same. We find the whole area of chemical engineering is susceptible to this variability. We find that judgment of the process designers moves factors one way or the other –perhaps intuitively–to accommodate these changing environmental factors. I feel we are really babes in the woods looking for a specific knowledge on the way these items of equipment work in our units. Certainly the field is wide open. We are not nearly so accurate and so scientific as we like to think we are.

Fallibilities

C.E.P. Editor: I'd like to ask Bob Wall if his work has to do with exploring what goes on in process lines.

Wall (Monsanto): That is my specialty, the analytical approach—in other words, reading the chemical composition of the process stream and not just recording the pressure or temperature. In addition to the problems of instrument development or application I think there is definitely an educational problem here. If something goes wrong in the process, there's a tendency to blame the instrument. There is a wide gap between the instrument performance level and the confidence level. An instrument will be 90% reliable and, if you check it closely, you know what it is doing, while operations people believe it only about 25% of the time. If it's 99% reliable, they might believe it 90% of the time. Eventually operators may become 95% confident.

C.E.P. Editor: In other words, are we undergoing human development at the same time we're undergoing mechanical development in process control?

Wall (Monsanto): People are developing slowly.

Getting Best Use

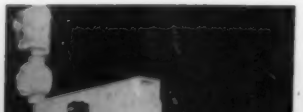
Grove (Amoco): Another subject of importance in the application of process controls has to do with the economics of the installation of new instruments. My company likes to see if a certain instrument that costs us, say, $1,000 or $2,000 will pay off. How do you go about justifying to the boss the purchase of this instrument just for smoother operating control? One can't say that it saves so many man-hours or man-weeks or that it makes a better product.

Draffen (Monsanto): How would one do that for instrumentation?

Grove (Amoco): I don't know, but I would like to know the answer.

Alexander: I think we can yet operate more economically by better utilization of instruments. On the opposite end of that line you may over-instrument, that is, waste money on too much instrumentation. You can be inclined to put instruments in which no one ever pays attention to after-

Alexander, Grove, and Walker listen intently.



The Separation Problem

wards. Someone insists that you must have a record of this and then you look into the matter after the plant is in operation and ask what they are getting from that recorder. What recorder? They don't even remember wanting it. That is over-instrumentation and it is an economic waste. Somewhere in between that is what you are shooting for and I think there are basic facts that can justify these things but you are dealing with differing basic philosophies with different management people.

I'm sure that everyone around this table has experienced a case where you thoroughly justified an instrument. You knew you needed it, you had to have it, and you put it in, and you found out after the plant had been in operation six months or a year that you didn't need the instrument at all. The operating people become accustomed to some degree of instrumentation and if they happen to be accustomed to a high degree of instrumentation, it is extremely difficult to argue them out of an instrument they want. We'll put it in and then if it isn't needed we'll take it out—but we'll put it in.

Hart (Dow): You have such an investment in a plant that you can't afford to have it not run, for lack of something like an instrument.

Alexander: If, however, we wait till the plant is on stream to study dynamics we've lost the advantage. Porter Hart is right in saying you've got to be sure that your plant is going to operate.

Secrecy

C.E.P. Editor: In the chemical industry is information about process control often regarded as representing competitive advantage?

Hart (Dow): I don't know. I believe that our company would say so. We don't have secrets–we have know-how and there are lots of data that can be published that aren't secrets, but we don't publish the know-how necessarily. I think that's quite true, isn't it?

Alexander: Yes, but I think the problem here is when you get down to talking specific instrumentation you are not talking secrets but you have to talk know-how to get into anything that's revealing about the usefulness of the instrumentation.

Hart (Dow): I think a classic example possibly of what you're talking about as far as our company goes is that I published a paper on the chemical process control system of the seawater bromine process. We gave the story on the control systems and everything for the whole process. That's a long way from the know-how of building a plant. However, the information was quite good and well received.

Alexander: In the petroleum industry the processes from plant to plant are so similar that it is much easier to publish almost anything.

Alexander, Grove, Walker, and Anderson. Still listening.

Help from Universities

Grove (Amoco): I would like to know how to start to stimulate interest in our universities for work on instrumentation. Why couldn't more advanced theses be written on instrumentation? I think every school has a fractionating column set up around some place and these columns have quite a few instruments. The auxiliaries on that tower are the real important things. The pumps don't always work exactly right, but no one thinks about them. The instruments don't always work right. We oversize and undersize valves. I think, if we understood the principle of what happens when you oversize a valve or undersize it or use the wrong instrument, then we could better understand what happens to our processes.

Alexander: I think something that bears on this is that up until recently no school of engineering was teaching anything on instrumentation that would give students any background for wanting to do such advanced work.

Draffen (Monsanto): My impression of most of the instrumentation courses being given in chemical engineering departments is that they are either "hardware" courses or automatic control philosophy courses with little mathematics.

Alexander: These you are criticizing are so recent, they may be a forerunner to better courses.

Draffen (Monsanto): I agree.

Hart (Dow): I think what the chemical engineering graduate students lack first of all, Jack, is the fundamental background of the basic measuring elements. Many of them don't know how to get a good temperature reading; they don't know how to get good pressure readings either. You have to get into things like this first before you can go on into feedback systems.

process control

Alexander: I agree, Porter, that too many fellows come out who attach far too much significance to the accuracy of the things they have been exposed to.

Finale

Hart (Dow): There's a lot of judgment back of controlling processes that comes from experience.

Wall (Monsanto): Plus that fact, process instrumentation is getting to be a highly specialized and technical subject–a subject that you can't treat casually if you want to take advantage of the latest advances.

Alexander: I think our general problem boils down to how the process engineer can obtain and utilize knowledge about control systems and control devices. Certainly a large part of this will mean going to the people who have the specialized knowledge and working with them in making the correct interpretation for practical advantage.

I believe that through the discussion held here at the instigation of C.E.P., we may have clarified some of the problems involved, and offered practical suggestions for their solutions.

The successful use of spectroscopy in the laboratory, for rapid and accurate

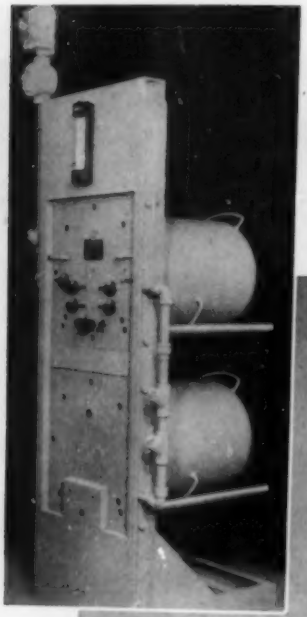
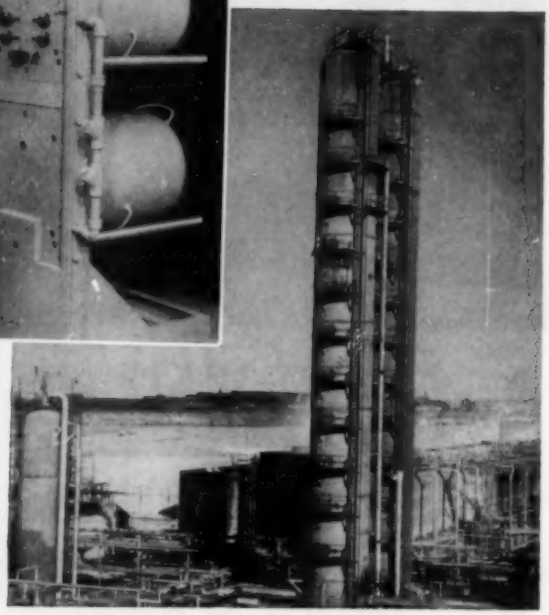


Fig. 4. Phillips automatic infrared analyzer.

Fig. 1. Furfural extractive distillation unit.



experience in controlling a large separations column with the CONTINUOUS INFRARED ANALYZER

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Summary

In an effort to determine the interrelationships of the various parameters of furfural extractive distillation column control, operations and control-system response of a commercial column were studied. This column, in Plains Butadiene Plant, Borger, Texas, performs the separation of 2-butenes from normal butane. The data derived from several periods of routine operation were studied so that normal operation and time of response to control action might be observed.

The primary column control element is an automatic infrared analyzer which continuously determines the butylenes content of a sample from the vapor phase of a tray midway between feed entry and the reboiler. The control signal from the analyzer's recorder is used to reset the lean furfural flow rate and thereby control the column's separation. This control system has been in use for several years, contributing greatly to economical operation.

The character of the response of related variables to step changes in the major independent variables was observed, and the lengths of time required for vapor and liquid flow in this large column were estimated. It was concluded that volumetric readjustment to operating change proceeds at a higher rate than the associated phase composition readjustment.

From this preliminary consideration of control problems arising from the frequently changing requirements for in-line fractionator operation, it was concluded that a greater knowledge of the system dynamics is necessary for optimum economic control. It is believed that frequency-response techniques may offer a more rigorous method of analysis.

The Separation Problem

In the two-stage dehydrogenation process for the commercial production of 1,3-butadiene from *n*-butane, an intermediate step consists of the separation of *n*-butylenes from *n*-butane. The purified *n*-butylenes are further dehydrogenated to 1,3-butadiene, and the purified *n*-butane is recycled to the primary dehydrogenation unit. The effluent C_4 hydrocarbons from the first dehydrogenation step consist principally of *n*-butane, 1-butene, and 2-butenes (*trans* and *cis* isomers). Simple fractional distillation is adequate for the separation of 1-butene from the other C_4 hydrocarbons, but a similar separation between *n*-butane and the two isomeric 2-butenes by straight fractionation is not practical because *n*-butane and *trans* 2-butene have nearly the same volatility. Consequently, furfural extractive distillation, or some similar process, must be employed for the purification of the combined 2-butenes (*1*).

Furfural as a selective solvent (liquid-vapor contacting) alters the normal relative volatilities of the C_4 hydrocarbons. In general, the more unsaturated hydrocarbons are more soluble in polar selective solvents. Therefore, in an extractive distillation column where a mixture of *n*-butane and 2-butenes (vapor phase) is continuously contacted by furfural (liquid phase), the 2-butenes tend to be absorbed in the solvent while the *n*-butane remains substantially in the vapor phase. The hydrocarbon-rich solvent is heat-stripped in an auxiliary column to recover the 2-butenes. Thus, a high-purity 2-butene concentrate is separated by an economical process from recycle butane having a low butylene content.

One disadvantage of the furfural extractive distillation process is the difficulty of operational control, as compared with the operation of simple fractionators. The control of product purities is complicated not only by fluctuations in feed compositions but also by variations in solvent temperature and variations in solvent composition, i.e., changes in concentration of solvent modifiers, such as water and oils in the system furfural. For several years, bromine orsat analyses offered operating personnel the only rapid control test for the separation of 2-butenes from *n*-butane. However, even the orsat analyses, although simple and convenient, could not be performed with the frequency required for efficient column control.

The Phillips Infrared Analyzers referred to are now called "Consolidated-Phillips" Infrared Analyzers, available from Consolidated Engineering Corp., Pasadena, Calif.

The successful use of spectroscopy in the laboratory, for rapid and accurate control analyses, has led to the development of on-stream analyzers which are installed in the plant to monitor process stream compositions continuously and automatically (*2*). In 1949 our Research and Development Department designed and constructed the first model of the explosion-proof automatic infrared analyzer for continuous analytical control of the butane–butylene extractive distillation column. In addition to recording continuously the concentration of butylenes in a sample stream, the analyzer automatically controls the rate of flow of furfural to the column.

An examination of the characteristics of the pneumatic control system incorporating an infrared analyzer-controller is presented below, together with a summary of the benefits derived from automatic composition control.

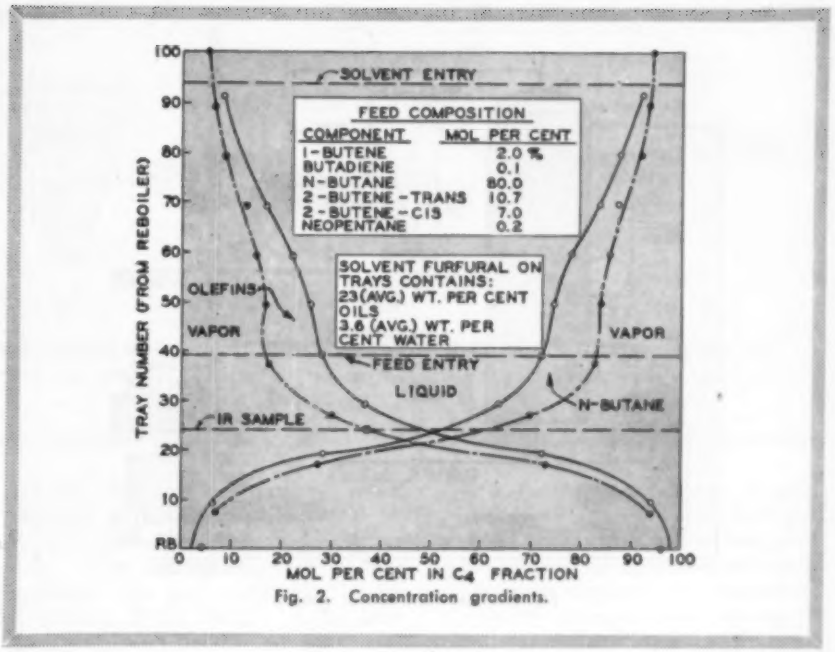


Fig. 2. Concentration gradients.

Column Description and Normal Operation

The furfural extractive distillation unit (absorber) is a 13½-ft.-diam., 100-plate column with bubble-cap trays. As shown in Figure 1, the column is erected as two 50-tray sections, 150 ft. high. Heat is supplied to the bottom of the absorber by passing 300 lb./sq.in. gauge steam through tube bundles in two external reboilers. The overhead product vapors are condensed in cooling-tower coils.

Liquid furfural is introduced into the extractive distillation column at the 94th tray (numbered from the bottom) and flows downward over the trays to the reboilers. The C_4 hydrocarbon feed (primarily *n*-butane and 2-butenes) is vaporized and passed into one of several entries located between the 35th and 59th trays. The top portion of the column acts to absorb 2-butenes. Heat supplied to the reboilers serves to strip out, in the bottom section of the column, the *n*-butane which is absorbed to some extent in the top section. The overhead product (primarily *n*-butane) is recycled to the butane dehydrogenation unit. Hydrocarbon-rich furfural from the kettle is pumped to a 20-tray stripping column where the C_4 hydrocarbons (primarily 2-butenes) are separated from the solvent. Lean furfural from the kettle of the stripper is cooled and recirculated to the absorber. Typical operating conditions and compositions of hydrocarbon streams are presented in Table 1. (See page 352.)

The performance of the extractive distillation column may be visualized further by reference to Figure 2, showing concentration gradients of the major C_4 hydrocarbons throughout the absorber column, and Figure 3, a plot of the temperature and pressure gradients. The compositions shown in Figure 2 are the result of operating conditions for a maximum load test and do not represent optimum separational efficiency.

Efficient operation of the absorber requires that the concentration of unsaturated C_4's in the overhead *n*-butane stream be maintained as low as possible. Experience has shown that analysis for olefin content in samples from the 24th-tray vapor space of the absorber constitutes an adequate method of control testing. Under normal operating conditions, if the concentration of unsaturated C_4's at the 24th tray is held within the range of 20 to 25%, the loss of olefins in the overhead product will be only 1 to 2%, while the purity of the olefinic hydrocarbons stripped from the rich solvent will be approximately 98%.

Prior to the installation of an on-stream infrared analyzer, bromine-orsat analysis was used to determine the concentration of olefins in control samples. The flow ratio of lean furfural to hydrocarbon feed being fixed, the rate of flow of steam to the reboiler was then adjusted to maintain the concentration of unsaturates at the 24th tray within the proper range for the desired separation in the column. Under these conditions, because of the impracticability of performing continuously orsat analyses, the hydrocarbon composition at the 24th tray deviated frequently from the desired control range, resulting in either excessive carry-over of olefins in the overhead product or high butane content of the purified butylenes.

In 1949 Research and Development Department of Phillips Petroleum Company designed and built an on-stream infrared analyzer (Figure 4) for the purpose of monitoring continuously the concentration of 2-butenes in *n*-butane. The analyzer has a nondispersive, filter-type optical system and is explosion-resistant in Class I, Group D hazardous locations. Following the successful application of the instrument for analyzing and recording the percentage of unsaturates in the 24th-tray vapor sample, the use of the analyzer was extended further by utilizing the pneumatic output signal from the recorder to reset automatically

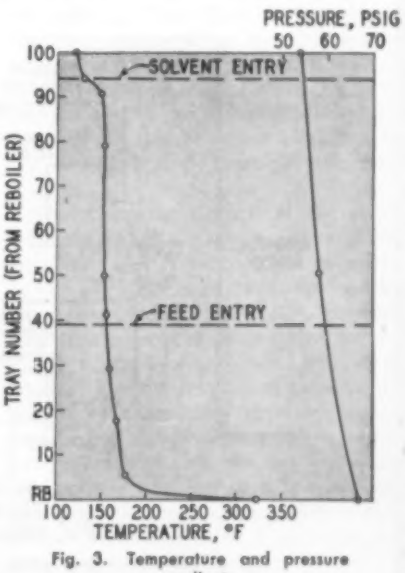


Fig. 3. Temperature and pressure gradients.

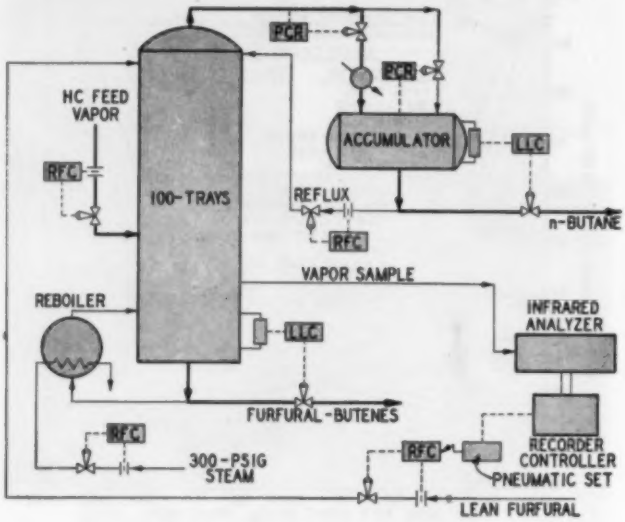


Fig. 5. Pneumatic control system.

the rate-of-flow controller on the lean furfural stream. The complete control system utilizing the on-stream infrared analyzer-recorder-controller is represented in Figure 5. The sample-handling system associated with the analyzer is diagramed in Figure 6.

An example will serve to illustrate the operation of the control system. At fixed steam and hydrocarbon feed rates, if the olefin concentration begins to increase at the 24th tray of the absorber, the analyzer will record the increment. Simultaneously, there is a proportional increase in the output of controlled air from the recorder. This increase in air pressure, through a bellows, moves the set pointer (control index) on the furfural rate-of-flow controller, which opens the motor valve farther and allows a larger volume of furfural to enter the column. The additional solvent absorbs additional butylenes, causing a decrease in the concentration of unsaturates at the 24th tray, and the analyzer recording pen shortly returns to its control-point position. Control is effected then by changing the relative proportions of overhead and kettle products, thus allowing a desired compromise to be made between these terminal stream compositions. The maximum furfural rate variation allowed to the analyzer is about ±5%, or, at normal operating conditions, 180,000 ± 9,000 gal./hr. This cascade control permits very precise adjustment of a critical variable, and its narrow range prevents overcontrol because of major changes in other variables or malfunction of any portion of the control system.

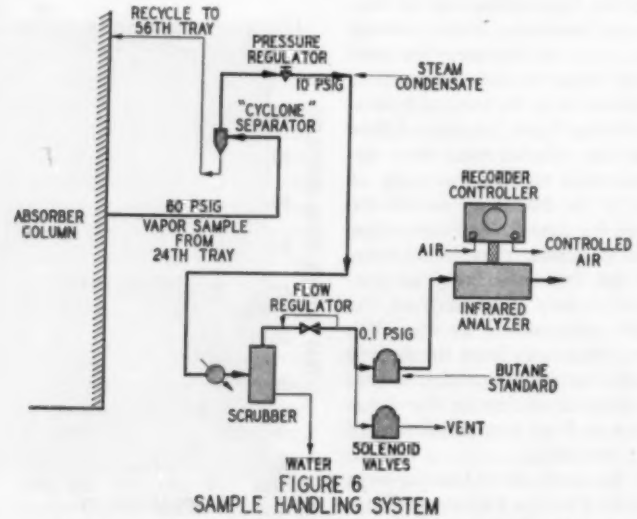


FIGURE 6
SAMPLE HANDLING SYSTEM

Fig. 6. Sample-handling system for on-stream infrared analyzer.

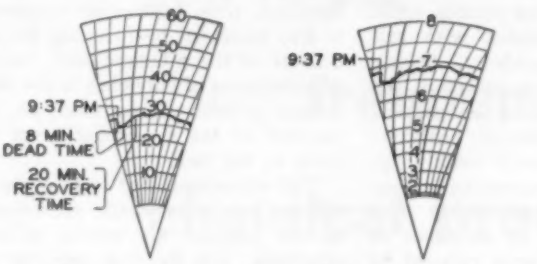
Operation of the Control System

Since it was possible to achieve this composition-influenced type of control system with commercially available instrumentation, it appeared desirable to study the system in more detail. It seems that most fractionating columns are designed with only steady-state conditions assumed. Since operations seldom are this ideal, it is believed that contributions of "dynamics" knowledge will assist design, operating, and process-control groups alike.

Little is known of the time lags in the control loops of our processes, i.e., the length of time required for the passage of transient conditions through equipment of this size. A new type of study, commonly called "systems engineering," has developed recently, its purpose being the better economic control of manufacturing processes. The experts in this field appear to prefer the frequency-response method of servo-system analysis. However, this technique was not employed here; rather, this study is preliminary to a more detailed control-system analysis (*3, 4*).

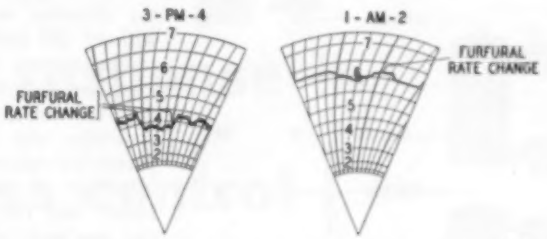
As is evident from the control-system diagram (Figure 5), only one control loop includes an appreciable section of the column. This loop comprises the sample from the 24th-tray vapor space, the automatic infrared analyzer and its recorder-controller, the air signal line to the pneumatic set bellows of the lean furfural rate-of-flow controller, and the furfural flow path down the column, including the vapor–liquid composition relations due to the tray-by-tray contacting. The transfer of information and action around this loop is of utmost importance to the controllability of this column, and the time lags need to be known, reduced where possible, and appreciated by operations personnel.

Major changes in this column's operation are usually the consequence of intentional feed-rate changes. Then, manual changes are made in the furfural rate (if beyond the range of the pneumatic set) and in the steam rate. As a result of these changes, both the volumes and compositions of the terminal streams adjust to the new operating conditions. The time lags from the readjustment of feed, steam, and furfural rates to the responses as shown in the terminal



ANALYZER-CONTROLLER CHART FURFURAL FLOW RATE CHART

Fig. 7. Infrared analyzer control of furfural flow rate.



OVERHEAD PRODUCT FLOW RATE KETTLE PRODUCT FLOW RATE CHART

Fig. 8. Typical response to control system action.

streams are also of considerable interest since they involve the transfer of sizable volumes of material over appreciable distances. Also, these lags set the requirements for the over-all control system since it is desired to approach the ideal of constant product volume and composition.

Column operation was observed for several periods, and considerable routine recorded data were studied, so that time lags might be measured and that familiarity with operating technique might be gained. Considering the control loop which includes the infrared analyzer and the flow of furfural to the column, it has been determined that an appreciable time lag exists between an adjustment of the furfural rate and the first indication of the response to this change exhibited by the infrared analysis of the 24th-tray vapor. Furthermore, there is an additional period required for this response to approach completion, which it does in the form of an S-shaped curve. This latter period, particularly, is influenced by the magnitude of the change in furfural flow. A typical example is shown in Figure 7: while under steady operations, as shown by recorder charts, a restandardization correction to the analyzer's calibration took place. The recording pen suddenly dropped from 24 to 22% unsaturates and caused a similar decrease in furfural flow. This same effect could be achieved by raising the analyzer's control point. A period of 8 to 10 min. passed before any evidence of the furfural rate change appeared on the analyzer's recorder. An additional period of some 20 to 25 min. was required for the analyzer to reach its new control level. Since the analyzer was "overriding" the furfural flow controller, as the analyzer approached its control point, the furfural flow was gradually increased until nearly all of the 5% reduction had been regained. This control action was observed a number of times, and in cases where the limits of the pneumatic set mechanism were reached, the 24th-tray analysis would continue to drift for a period of 1 hr. or more before reaching an equilibrium value. The "dead-time" of 8–10 min. appeared to be quite independent of the magnitude of the change. It has been determined that only a few seconds of that period are due to transmission of the pneumatic set air signal and the response of the furfural flow control loop. Approximately 2 min. of this time lag are due to the transmission of 24th-tray vapor through the sampling system and to the lag in the analyzer itself. This leaves some 6 to 8 min. required for a change in furfural flow rate at the 94th-tray entry to be sensed in the 24th-tray vapor. It should be noted here that the transient response of the infrared analysis to a step disturbance in furfural rate, when the system operates as a closed loop, will be different from the response obtained when the loop is open and the step disturbance is maintained throughout the test period. For this and other reasons, further interpretation appears difficult and probably frequency response techniques will be more applicable (*5*).

Some experimentation for the purpose of determining "dead-time" with reference to the other column variables was performed. Since a change in furfural flow rate changes the relative proportion of overhead and kettle products, it was noted that the overhead product rate begins to change about 5 min. after a furfural rate change is made and moves to its new level within another 5 min. This action is probably influenced by the volume holdup in the condensing coils and accumulator and by the characteristics of the liquid level control. A change in furfural rate also appears in the rich furfural flow rate from the reboilers. Since there is volume holdup at the base of each column section and in the two reboilers, this system has some inertia. It was observed that about 15 min. was required for a step change in lean furfural rate to appear as a similarly well-defined step change in kettle-product rate. This may be contrasted with the composition action determined by the analyzer, as mentioned previously.

The times required for transmission of changes in vapor flow rate up the column may be derived from the following: an increase in hydrocarbon feed rate of about 12% was evident in the overhead product after about 10-min. lag and exhibited about the same actual volume change after another 10 min. No noticeable change was evident in the analyzer record from this feed increase. An increase in reboiler steam rate of about 5% was evident on the analyzer's chart after 5 min. and continued during the next hour to increase the unsaturates in the tray vapor from 20 to 24 mole %.

at which time the analyzer was put back into control service to prevent upset of the column. The effect of this steam-rate increase appeared as an overhead product rate increase after about 12 min., rising to an equilibrium value in another 5 min. Figure 8 shows typical response to control action exhibited by the overhead and kettle-product flow systems.

To attempt to summarize the above information, a change in liquid-phase flow rate within the column is sensed by the 24th-tray vapor analyzer and by the kettle-product flow recorder after time lags somewhat proportional to the length of the flow path: i.e., tray 94 to tray 24, 7 min.; tray 94 to reboiler, 15 min. The times then required to approach final values, however, are widely different since with the kettle-product volume it is a matter of a few minutes and with the composition it may range upward from 5 min. to 1 hr. or more. (See Figure 9)

Similarly, the first sensing of a change in vapor-phase flow rate caused by

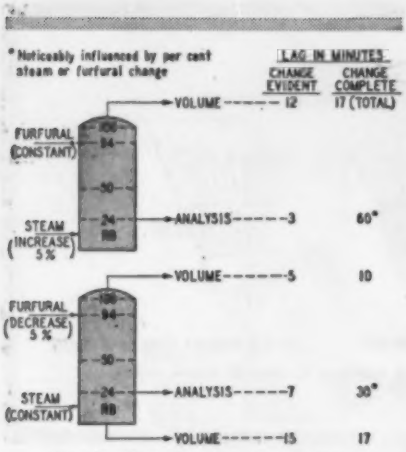


Fig. 9. Control response time lags.

steam-rate change is somewhat proportional to the flow-path length: i.e., reboiler to tray 24, 3 min.; reboiler to overhead product, 12 min. Again the 24th-tray composition required much more time to complete its change than did the overhead product volume.

Previous observations and test data indicate that, although terminal stream volumes may change rapidly, their compositions normally change slowly, requiring several hours to drift from minimum to maximum of a composition cycle. This feature and the high sensitivity to concentration gradient change available on a well-selected tray are regarded as the basic reasons for the workability and the success of this type of composition-influenced automatic control system.

It is evident that efforts should be made to reduce the control-loop "dead-time" due to the analyzer as well as that due to the furfural flow path. Possibly a more detailed series of experiments with various configurations of control instruments would produce a further improved control system. However, the time required for readjustment of the concentration gradients (the composition relations of the liquid and vapor phases) is thought to be the major controlling factor in control-system response.

Benefits of Composition Control

The most tangible benefit from the installation of an infrared analyzer-controller is the stabilizing influence on the composition of material being processed. When orsat analysis was the control test for the extractive distillation column, the fluctuation in olefin content at the 24th tray amounted to an average deviation of ± 10% absolute from the desired concentration. With analyzer monitoring and control, the variation has been reduced to approximately ± 3.5%. In order to evaluate more closely the benefits of such apparently smoother operation, further observations were made during comparative periods while the absorber was operated with and without the infrared analyzer. Owing to fluctuations of many variables, the improved degree of separation possible with the use of the automatic analyzer-controller was not always readily apparent throughout the comparative tests. However, it was conservatively estimated that the losses of butylenes in the overhead product were reduced by 25%, equivalent to an increase in recovery of butylenes from 89 to 92%. The improvement in efficiency and increase in column capacity at maximum production rates will pay off the cost of an on-stream analyzer in a few weeks.

The reduction in butylene content of the recycle butane assumes added importance when it is realized that butylenes are much more susceptible to coking than butane under the conditions of catalytic dehydrogenation. A high rate of carbon deposition contributes to shortened catalyst life. The net yield of butylenes from butane dehydrogenation is also increased by reducing the olefin content of the *n*-butane feed, since the concentration of butylenes in the effluent stream is relatively constant, i.e., independent of the concentration of butylenes in the feed.

The educational and training features offered by an automatic recording on-stream analyzer are worthy of special emphasis. For the first time, the operator has a reliable means of gauging immediately the magnitude of fluctuations in operating conditions, and he can apply corrective measures without delay. Even the most highly trained operator cannot match the continuous monitoring offered by the analyzer. The availability of a continuous record of hydrocarbon composition creates additional interest and facilitates the study of column performance by both operating and technical personnel.

Table 1.—Typical Operating Conditions
Butane–Butylene Extractive Distillation Column

	Flow Rate, gal./hr.	Temperature, °F.	Pressure, lb./sq.in. gauge	Composition of C_4 Fraction, mole %				
					2-Butenes			
				n-Butane	*trans*	*cis*	1-Butene	Other C_4's
Reflux	10,000	90	54	98.0	0.4	0.1	1.0	0.5
Overhead product	16,000	90	54	98.0	0.4	0.1	1.0	0.5
Lean furfural	180,000	110						
Feed (39th tray)	21,000	125	..	74.0	13.5	10.5	1.5	0.5
Rich furfural	185,000	300	67	2.5	52.0	41.5	3.0	1.0
Steam (to reboilers)	200,000 lb./hr.							

Estimated System Holdups:

Column	
Hydrocarbon	18,000 gal.
Furfural	60,000 gal.
Overhead Product Accumulator	
Hydrocarbon	20,000 gal.
Reboilers (2)	
Furfural	40,000 gal., total

Acknowledgment

This paper includes the results of work performed as part of a plant research project sponsored by the Federal Facilities Corporation, Office of Synthetic Rubber, in connection with the government synthetic-rubber program. The authors wish to thank all company personnel who contributed both to the success of the instrument development program and to the preparation of this paper.

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Presented at A.I.Ch.E. meeting, Houston, Tex.

HOW TO USE

frequency response in chemical process control | PART I

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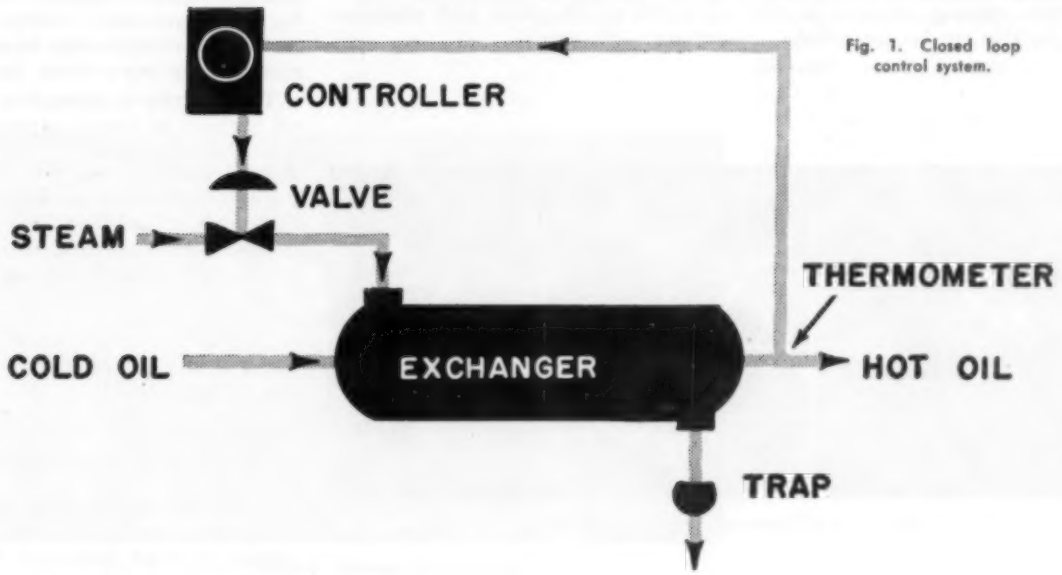

Fig. 1. Closed loop control system.

Recent rashes of publicity and promotional activity regarding push-button factories, automation, and the use of giant brains to relieve humans of much of their work attest to a growing popular recognition of the economic importance of automatic controls. The chemical process industries, of course, have recognized this importance all along, and the smoothly running depopulated plants are impressive witnesses of this fact.

Despite their reliance on automatic controls, however, chemical engineers have contributed little toward the science of control. Perhaps they have been preoccupied in mastering the processes and operations of chemical engineering, or perhaps the formidability of a rigorous mathematical approach to control problems has been a deterrent. Whatever the reason, the fact remains that the average chemical engineer today has an inadequate grasp of control principles. His understanding of why a particular control system is required for a particular process is vague and qualitative at best, and his design and planning of processes and equipment often fail to include adequate consideration of control problems.

It is neither necessary nor desirable that all chemical engineers be control engineers, but in view of the rising proportional investment in instrumentation and the trends toward faster reactions and tighter control of yields and quality, it is important that the underlying principles of automatic control be understood. Chemical engineers are ultimately responsible for the successful operation of process plants; and successful operation depends as much on good controls as it does on properly designed process components.

Unfortunately there are no textbooks available today which specifically treat chemical engineering control problems in a quantitative manner. Farrington's "Fundamentals of Automatic Control" (*4*) and "The Dynamics of Automatic Controls" by Oldenbourg and Sartorius (*6*) present analyses of some types of processes, and the books of Ahrendt and Taplin (*1*), Brown and Campbell (*2*), Chestnut and Mayer (*3*), and Thaler and Brown (*7*) provide introductions to servomechanism principles. The recent A.S.M.E. symposium on frequency response (*5*) includes a number of summary articles, recommendations for standardization, and extensive bibliographies.

It is the purpose of this article to present a simple treatment of process control principles in terms of frequency response characterization. A subsequent article will elaborate on these principles and show how they may be applied profitably.

OPEN-LOOP AND CLOSED-LOOP CONTROL

The function of a process controller is to maintain some key process variable equal at all times to some desired value, which usually will be a constant for continuous operations but which may vary with time for batch operations. Ordinarily this desired value is fed manually into the controller as a command signal or set point. On the basis of the command the controller sends a corrective signal to the final control element, which may be a motorized valve. Manipulation of the valve by the controller moderates a process flow stream causing changes in the process variable to be controlled.

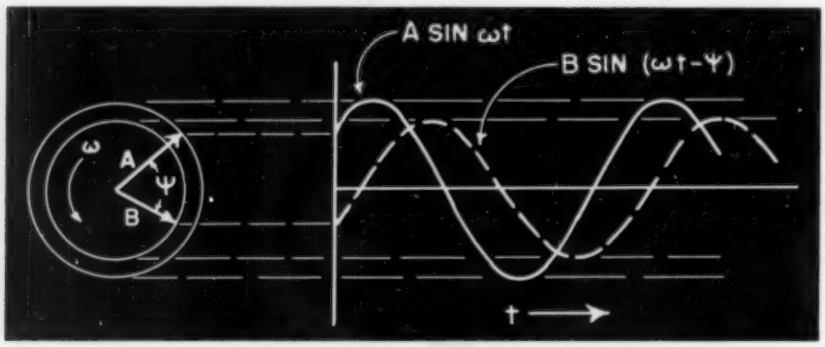

Fig. 2. Vector representation of sine waves.

If the controller action is dictated by the magnitude of the set point alone, the controlled process is an open-loop control system. An example of open-loop control is a steam-oil heat exchanger wherein a pressure regulator is adjusted to hold the steam at the particular pressure which will produce the proper hot oil temperature under normal conditions. Any departure from these normal conditions results in a departure of the outlet oil temperature from the desired value. Open-loop control is effective only if the normal conditions remain constant and if the calibration between regulator setting and oil temperature is precise. These requirements usually make open-loop control uneconomic.

If the controller action is dictated by the difference between the set point and the controlled variable, that is, by the *deviation* of the variable from the set point, the controlled process is a closed-loop control system. Figure 1 shows a simple steam-oil heat exchanger in a closed loop. The outlet oil temperature is sensed by a suitable thermometer and fed back to the controller, thus closing the loop and ensuring that the controller is always apprised of the effectiveness of its control action.

CONTROL-SYSTEM DESIGN

Figure 1 suggests the basic problems of designing an effective controlled system. Given the process duty, namely oil flow rates, inlet temperatures, desired outlet temperatures, and allowable fluctuations, how can one design the exchanger and select the measuring instrument, controller, and control valve which in consort will meet the performance specifications with minimum cost per unit time?

It is usually a simple matter to specify what the desired value of the controlled variable should be. It is not so simple to specify allowable fluctuations. In some processes any cycling of the controlled variable is undesirable because of the possibility of amplified cycling in processes downstream. In other processes sustained oscillation is not objectionable provided the amplitudes are less than some specified amount. Since the normal function of a process controller is to maintain the controlled variable constant despite a variety of random disturbances, it is customary to specify control performance in terms of the controlled response to an arbitrary and severe disturbance. The simplest to apply and one of the most severe disturbances is a step function, in which there is a sudden shift in a variable from an initial steady-state condition to some new constant condition. Usually the variable being shifted is the set point, and the resulting behavior of the controlled variable is called the *transient response*. For most process control systems an optimum transient response is one which initially does not overshoot the final steady-state value by more than 20 or 30% of the total jump from the initial to the final steady value and in which the amplitude of succeeding cycles subsides in a ratio of about 3:1.

If this transient response is the criterion of acceptable performance, then in principle it is only necessary to write the equation for this response and compute from it what economic combination of process and instruments will be required. In practice such computation is virtually impossible except for the simplest systems. Even the use of an analog computer to permit a large number of trial-and-error calculations is beset with great uncertainty because of inaccuracies in representing the process.

The difficulty in attempting theoretical analyses of control systems by this transient behavior lies in the fact that it is necessary to use the solutions of the differential equations which describe the system. These solutions are unobtainable for the general case, and for simple real systems are awkward to handle.

FREQUENCY-RESPONSE ANALYSIS

Just prior to World War II new techniques based on frequency-response characterization were applied to the design of servomechanisms or position controllers. During the war the development of these techniques was given great impetus by the need for accurate steering and firing controls for military purposes, and now these same techniques are being applied on a modest basis to process control problems.

If a sustained sinusoidal variation is induced in some property of an inlet stream to a process, the same property of the corresponding outlet stream will also vary sinusoidally and at the same frequency. However, the outlet waves will lag behind the inlet waves, and their amplitude usually will be less. The ratio of the amplitudes of outlet and inlet waves and the phase angle between them over practical ranges of frequencies constitute the frequency-response characteristics of the process.

In a typical case the input to a system is a steady-state sine wave of amplitude A given by $A \sin \omega t$, where ω is the angular frequency in radians per unit time and t is time. The corresponding output is also a sine wave given by $B \sin (\omega t - \psi)$ having identical frequency but with a smaller amplitude B and

displaced in phase by the angle ϕ. The particular variable involved might be temperature or composition, for example, and the particular process might be one of heat exchange, chemical reaction, or the like.

In Figure 2 the amplitude, phase angle, and frequency are identified by representing the sine waves as rotating vectors. The relation between cyclic frequency and angular frequency is that the latter in radians per unit time is 2π times the former in cycles per unit time.

At a given frequency the magnitude ratio of the output and input wave amplitudes and the phase angle between the waves depend solely on the properties and nature of the process, hence it is possible to analyze the process from its frequency-response characteristics. Conversely from a knowledge of the properties and nature of the process, it is possible to calculate the frequency-response characteristics. The important advantages of characterizing dynamic systems by means of frequency response are that only two quantities are involved, namely magnitude ratio or gain, as it is often called, and phase angle, and the manipulation of these quantities is simple.

For linear systems composed of a series of components which do not interact, the over-all gain is the product of the individual component gains, and the over-all phase angle is the sum of the individual component phase angles. Most systems behave linearly for small changes. If there is interaction between the stages or components, that is, if upstream stages are affected by downstream stages, effective time constants can be computed which retain the simplicity of the relationships between noninteracting components.

OPEN-LOOP FREQUENCY-RESPONSE CHARACTERISTICS AND STABILITY

By plotting the logarithm of the gain (magnitude ratio) and the numerical value of the phase angle against the frequency, one notes that both characteristics become additive properties. The over-all open-loop frequency-response characteristics of a typical control system are obtained graphically by adding the individual gain curves and the individual phase curves.

Usually the frequency abscissae are put on a logarithmic scale to facilitate plotting, and both gain and phase curves are drawn on the same sheet. The resulting plots are called Bode diagrams. Figure 3 is a typical diagram for an industrial process similar to that in Figure 1.

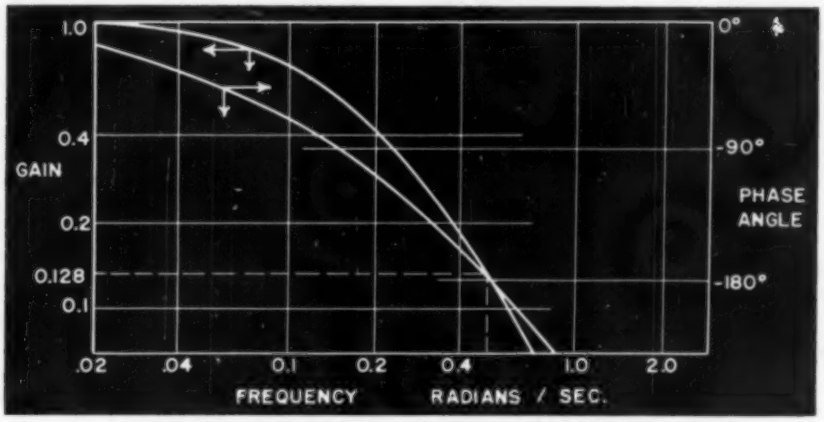

Fig. 3. Process frequency response characteristics.

Open-loop frequency-response characteristics of controlled process units may be determined experimentally by applying a sinusoidal signal to the control valve motor after the controller output has been disconnected. For example, air pressure regulated sinusoidally through a mechanically driven reducing valve can be applied to the motor on the steam valve of Figure 1 in place of the air pressure coming from the controller. This pressure to the valve would constitute the input signal to the open loop, and the recorded outlet temperature of the hot oil would constitute the output signal. The air-pressure reducing valve would be driven at enough frequencies to cover the pertinent ranges and at each frequency enough time would be allowed to ensure elimination of all transient effects.

From records of the sinusoidal input and the corresponding process variable output the gain and phase data can be extracted. In computing the magnitude ratios the air pressure inputs must be converted to the equivalent steady-state outlet temperatures.

Frequency-response characteristics are related inherently to control-system stability, and stability is the basic requirement in automatic process control. The dividing line between stability and instability in a controlled process or system is the condition where a disturbance introduced at any point in the system leads to sustained oscillation of the controlled variable. Under more stable conditions the effect of the disturbance would be attenuated, and, although the response might be periodic, in time the cycling would disappear. Under less stable circumstances the response to a disturbance would be cyclic with the amplitude increasing until the system reached a new point of balance or until some component of the system broke down.

If the conditions requisite to stability in a system can be identified, it is possible to choose the proper combination of control elements. Frequency-response analysis provides a simple means of identifying these conditions, and, although the precise adjustment of control elements cannot be predicted generally, the use of simple empirical rules affords a good first approximation.

It is convenient to measure the stability of processes in terms of the ultimate gain of a proportional controller. Ultimate gain is the minimum controller gain necessary to make the controlled process unstable when a proportional controller is used for regulation. Proportional control, the simplest and most important type of continuous control, produces a controller output proportional to the deviation but opposite in sign. Its frequency-response characteristics for all practical frequencies are a magnitude ratio equal to the proportional gain and a phase angle of —180 deg.

In typical industrial processes the open-loop phase lag (negative phase angle) increases with frequency and ultimately exceeds 180 deg. The frequency corresponding to 180-deg. phase lag is the *ultimate frequency*, and the reciprocal of the process magnitude ratio at this frequency is the ultimate proportional gain. Closing the control loop of a process having 180-deg. phase lag by means of a proportional controller makes the over-all phase lag 360 deg.

so that the output from the controller is in phase with the input to the process. Thus, if the gain in the controller is sufficient to offset the gain (actually an attenuation) in the process, any disturbance to the system will be sustained, and continuous cycling will result. In order for the controller gain to offset the process attenuation the product of the two must equal unity, hence the ultimate controller gain is the reciprocal of the process gain.

Consider the frequency-response characteristics of Figure 3. The process represented by this diagram could be the small heat exchanger in Figure 1, having a pneumatically driven steam valve, a low capacity but high flux exchanger, and a bare wire thermocouple installed in the outlet line at a point downstream such that there is a small but finite time delay before oil leaving the exchanger reaches the thermocouple. From the curves it can be seen that the ultimate frequency is 0.5 radians/sec., and the ultimate proportional gain is 1/0.128 or 7.8. Generally, if the ultimate proportional gain exceeds 20 or 30, an inexpensive narrow-band proportional controller will provide satisfactory control. For smaller ultimate gains it is necessary to use a more expensive broad-band proportional controller, usually in conjunction with *integral control* (automatic reset) and possibly *derivative control* (rate action). Since the ultimate gain is much less than 20, the system of Figure 3 would require a proportional plus integral controller, and, if a more rapid response were required, a three-mode controller (proportional plus integral plus derivative) would be necessary.

An important disadvantage of proportional control is that it permits a sustained deviation of the controlled variable from the set point. Proportional action merely provides a particular controller output for a particular deviation. Therefore, the controlled system, following a load change, can level out only with a sufficient deviation to ensure enough controller output to balance the new load. This deviation is called the *offset* or *load error*. With narrow-band (high gain) proportional controllers the offset is small, but with broad band proportional controllers it is excessively large.

Offset can be eliminated by adding integral control to the proportional action. Integral control produces an action which is proportional to the time integral of the deviation, that is, the control action changes with time at a rate proportional to the deviation. Thus integral control always seeks to reduce the deviation to zero, thereby eliminating offset. Adding integral control has the disadvantages of reducing the response speed and decreasing somewhat the over-all stability. These disadvantages often can be overcome by adding derivative control, which generates an action proportional to the rate of change of the deviation.

Derivative action can be used to reduce offset in addition to increasing response speed. It is a stabilizing mode in that it increases the ultimate proportional gain. Since the normal operating proportional gain would be increased to the same extent as the ultimate gain, there would be a corresponding decrease in the offset.

Many instrument manufacturers have worked out empirical rules based on ultimate gain and ultimate frequency for adjusting their controllers for optimum performance; hence, a knowledge of the ultimate gain and frequency of a process permits predicting not only the type of controller required but also how its control actions should be preset. If the frequency-response characteristics of the various process components are known or can be computed, the over-all controlled system design can be worked out from a few design rules involving these characteristics. Furthermore, the design of the individual components can be altered to improve their frequency-response characteristics and therefore improve the over-all control performance.

As a specific example of how the design of process components can be altered to advantage, consider again the system characterized by Figures 1 and 3. One immediate improvement that can be made is to eliminate the time delay by locating the thermocouple nearer the exchanger. However, there is no convenient means of gauging the effect of this alteration except in terms of the effect on the process frequency-response characteristics. As will be shown in Part II, this effect can be computed simply and precisely. In the present example the removal of a 1-sec. time delay would decrease the phase lag sufficiently to increase the ultimate frequency to more than 0.8 and the ultimate proportional gain to 20, with the result that a narrow-band proportional controller could be used instead of a more expensive multimode controller.

How frequency-response characteristics may be determined for processes and control components and how they may be used quantitatively in evolving an effective controlled system design will be described in Part II.

NOTATION (control terms)

automatic reset . . . see integral control

broad-band proportional controller = proportional controller with gains adjustable, *e.g.*, from 50 to less than 1

derivative control = control mode in which the controller output is proportional to the time rate of change of the deviation

deviation = difference between set point and controlled process variable

frequency response = response to steady-state sinusoidal forcing

gain . . see magnitude ratio

integral control = control mode in which the time rate of change of the controller output is proportional to the deviation

load error . . . see offset

magnitude ratio = ratio of amplitudes of output to input sine waves

narrow-band proportional controller = proportional controller with gains adjustable, *e.g.*, from 50 to 10

offset = steady-state deviation

phase angle = time displacement of output sine wave relative to input wave, usually expressed in degrees

phase lag = negative phase angle

proportional band = reciprocal of proportional gain, usually expressed in per cent

proportional control = control mode in which the controller output is proportional to the deviation

rate action . . . see derivative control

set point = setting on controller corresponding to the desired value of the controlled variable

transient response = time variant response to a sudden disturbance such as a step function

ultimate frequency = frequency at which the open loop process phase angle is —180°

ultimate proportional gain = gain in proportional controller which just causes sustained cycling when the control loop is closed

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A GUIDE TO
continuous stream analysis
IN THE CHEMICAL PROCESS PLANT

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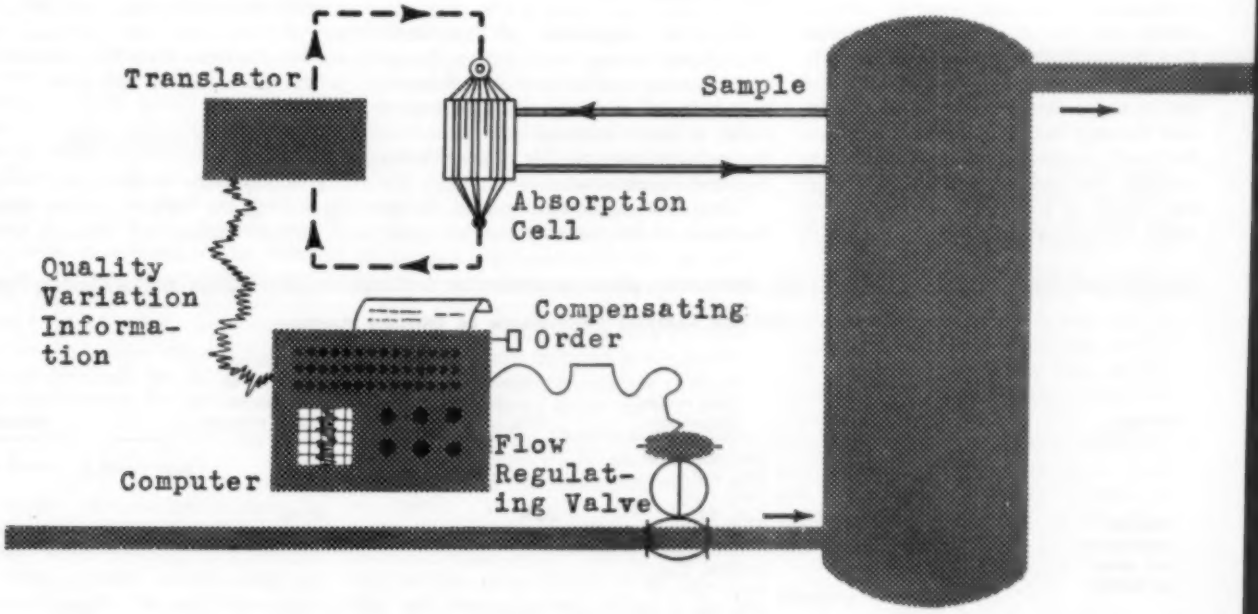
Continuous analytical control instruments, typified by the infrared analyzer, are eliciting increasing attention from chemical engineers interested in what these relatively new devices can do for processes under their supervision. The importance of these devices is indicated by the likelihood that they may be the first major class of control devices to take the chemical process industries into the actuality of completely automatic units. With all the material published, however, little space has been devoted to directing the chemical engineer toward their practical applications. The following comments are designed to provide him with a starting point for his inquiry into continuous analytical control as an aid to his own processing needs.

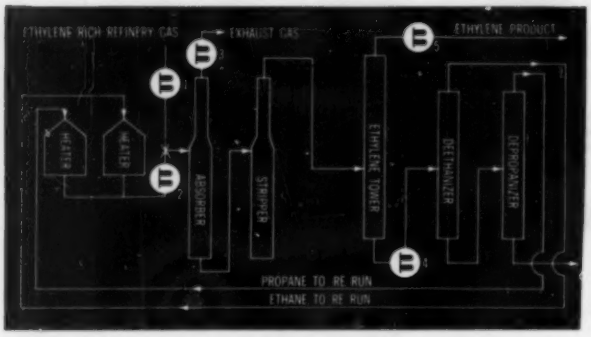
To begin with, it should be understood that continuous analyzers are a novel class of instruments—for the most part they will not replace or obsolete any instruments now in common use. Almost all the existing instruments in a processing plant are designed to control the process stream *environment*—temperature, pressure, flow rate, etc. The analyzers measure stream *composition*. The information they provide will be used eventually to set automatically the environmental controllers and hence "close the loop" between the product and the environment in which it is produced. In essence they take over the function of the control laboratory with a considerable increase in speed and efficiency.

Good for Old As Well As New

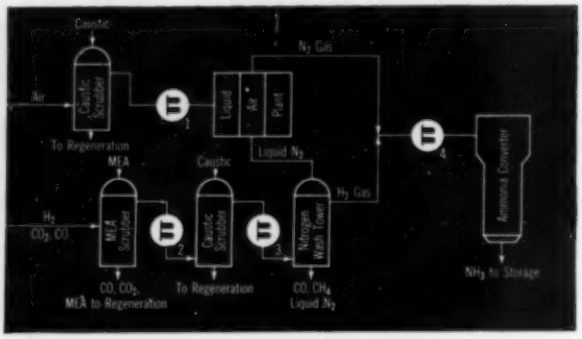
Let us consider some of the general applications for which continuous analyzers are well suited. So far, initial



Continuous analytic monitoring of process streams enables one to be constantly informed as to the quantitative molecular make-up of the contents flowing through vessels or pipelines. Such information brings to the plant operator a much closer coordination between his manipulation of key variables (such as pressure, flow rate, temperature, etc.) and the effect of this on the process. Some day—perhaps sooner than some think—a computer will "close the loop" between the continuous analyzer and the control elements (such as regulating valves) making the control decisions automatically, based on predetermined "instructions."



Use of Tri-Non analyzers in ethylene purification. Purity and maximum recovery is guaranteed at five points: 1—Ethylene analysis on feed stock for accounting purposes and process control; 2—Ethylene analysis beyond crackers; 3—Ethylene analysis of absorber off-gas for absorber efficiency; 4—Ethylene analysis in ethylene tower bottoms for fractionation tower efficiency; 5—End-point analysis for ethylene purity.



Use of Tri-Non analyzers in ammonia synthesis: 1—Analyzer determines optimum balance between caustic use and CO_2 removal efficiency; 2 & 3—The same analyzer is used for synthesis gas stream and to measure CO_2 level of input to MEA and caustic scrubber; 4—Analyzer measures p.p.m. of CO content of final mixture sent to catalyst. Tri-Nons increased plant efficiency by 10%.

installations have been made mostly in new construction. This is perhaps quite natural since it is usually easier to apply new techniques there than in plants already existing. In certain cases, too, as in some of the new acetylene-from-hydrocarbon processes, the process is so critical that the close control available only by continuous analysis is a necessity. Yet, studies of older chemical plants often indicate that continuous analytical control instruments can be of extreme importance here also. Their use may well lead to increased throughput through the ability to operate closer to safety limits and through better material utilization. Reduced manpower requirements are another common benefit. Such savings can make a marginal or obsolescent plant competitive again and at a small fraction of the cost of a completely new installation.

Typical Benefits

When a particular process is being studied, some specific areas where continuous analysis can pay handsome dividends are as follows.

RAW MATERIAL FEED

Does the composition of raw materials change enough to require a change in processing conditions? Would better knowledge of raw-material composition result in better material utilization? If so, analyzers may be able to provide the required information.

Often raw materials are paid for on the basis of the concentration of a particular component. Analyzers can provide accurate records for accounting purposes.

REACTORS

Is the proper material balance being maintained? Are there excess or unwanted components in the product streams? Are catalysts working properly? Is there anything in the feed stream that could poison a catalyst? In any of these cases the continual information available from the analyzers can permit more efficient operation.

SEPARATION AND PURIFICATION

Are separator towers and strippers recovering the highest possible amounts of desired materials? Does a purified

Table 1.—Tri-Non Analyzer Performance on Ethylene Analyses

Process	Recorder range full scale	Other stream components	Equivalent readability (1% of scale)	Stability, 8 hr. or longer (2% of scale)	Remarks
Ethylene manufacture and initial purification	5% C_2H_4 or greater e.g., 0-5%, 55-60%, 20-80%, etc.	Any mixture of CH_4, C_2H_6, C_3H_8, C_2H_2 C_2H_2, CO, CO_2, N_2	.05% C_2H_4	0.1% C_2H_4	
	2% C_2H_4 or greater, e.g., 0-2%, 24-26%	0-100% C_2H_4, C_2H_2, CO, CO_2, N_2, $C_2H_6 + C_3H_8$ < 50%	.02% C_2H_4	.04% C_2H_4	C_2H_4 concentration below 50%
	99.5-100% C_2H_4, or wider range	CH_4, C_2H_6	.005% C_2H_4	.01% C_2H_4	analyzer actually measures impurities
Final purification	0-7500 p.p.m. CH_4	< 2% C_2H_6 + C_2H_2, remainder C_2H_4	75 p.p.m. CH_4	150 p.p.m. CH_4	
	0-5000 p.p.m. C_2H_6	< 2% CH_4 + C_2H_2, remainder C_2H_4	50 p.p.m. C_2H_6	100 p.p.m. C_2H_6	

product meet specification? Is it better than specification? It is sometimes more expensive in terms of wasted effort to produce better-than-specification material than that which just meets specification. Accurate continuous analysis permits the holding of a narrow specification range. It can also keep a close check on waste streams for excessive loss of valuable components.

END PRODUCT QUALITY CONTROL

Here, of course, is the most obvious use of continuous analyzers.

SAFETY

Analyzers can warn of the development of hazardous situations either in the proces streams or in the plant atmosphere. The measurement of dangerous materials in effluent streams is another application; records of this sort can also be important from a legal standpoint.

REDUCTION OF OPERATING MANPOWER

In any of the above applications and in many others, continuous analytical equipment may reduce manpower requirements such as expensive laboratory personnel or process operators. The economic facts indicate that wherever a man is replaced by an analyzer, the cost of the analyzer is paid out in three months.

If the chemical engineer has surveyed his process and found points at which continuous analysis would be a desirable addition, he is now faced with the problem of selecting the proper equipment. Here he would do well to spend some time in his control or research laboratory to familiarize himself with the analytical techniques in use there. Practically all types of continuous analyzers are descended from laboratory instruments. And, it would be reasonably safe for him to assume that any analysis carried out routinely in the laboratory could also be made on the process stream itself.

Various Types of Analyzers

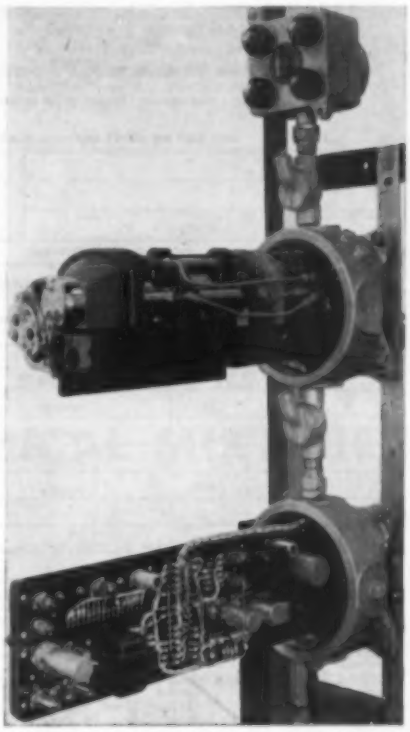
Just as the infrared spectrometer is the most generally useful laboratory instrument, so the infrared analyzer has proved to be the most widely useful on the process stream. Theoretically every organic material has a characteristic infrared spectrum which may be used to identify the material positively. In any continuous analytical problem, if the infrared spectrum of the component of interest has an absorption band which is relatively free from overlapping by the absorption hands of the other components present, then an infrared analyzer can be used to provide the desired analytical information through the relative intensity of the spectral band. The infrared spectra of many thousands of compounds have been published so that a fair idea of whether or not a given analysis can be handled by infrared can be formed rather quickly.

Typical performance of an infrared continuous analyzer in ethylene service is shown in Table 1.

Rather than list analyses that may be handled by infrared, it is perhaps easier to mention those that cannot. Notably among these are measurements of the homoatomic molecules O_2, N_2, and H_2. Here instruments based on other principles such as thermal conductivity may be used. Water is an extremely strong absorber of infrared radiation so that where high concentrations (above 10-20%) are present another method such as ultraviolet analysis must be chosen or the water removed prior to infrared analysis. In some hydrocarbon analyses where the total concentration of C_4's, C_5's, etc., are wanted, the continuous mass spectrometer may be the most efficient solution.

In addition there are three new analytical methods which show promise as eventual continuous control instruments. The first of these is the continuous refractometer which makes use of the fact that the index of refraction of a liquid is a characteristic of the components in the liquid and their concentration. The principle of vapor chromatography also appears to have tremendous potential in the analysis of streams made up of gases or low-boiling liquids. By this method, vapors are passed through an adsorption column which separates them according to their retention coefficients (Molecules are selectively delayed in their travel through the column in proportion to their affinity for the adsorbent material present.) Finally there is the new field of nuclear magnetic resonance spectroscopy which bids fair to match infrared in versatility, with the important advantage that excessive amounts of water do not upset its measurements. In fact n.m.r. spectroscopy may prove to be the long-sought method for detecting water in all media. In n.m.r. spectrographs, molecules are exposed to an intense magnetic field which causes them to tend to line up in the field as though they are tiny magnets. When a cross field of a given ratio frequency is applied some of them will shift to another position and in so doing absorb some of the r.f. energy. The frequency at which a particular molecule will shift or "resonate" provides a means for identifying that molecule.

Although similar in operating principle to their laboratory cousins, process stream analyzers differ in a number of important respects. Unlike the typical laboratory instrument which must be versatile enough to handle a wide range of problems, the process stream analyzer is usually sensitized at the factory for a particular analysis. Whereas it can be shifted from one problem to another, the modification must usually be made in the repair shop. The environment in which the analyzer is used also differs radically from the relative calm of the laboratory. Process stream analyzers must withstand wide ambient temperature fluctuations and heavy vibration, they must not create an explosion hazard, and often they must be able to withstand the onslaught of monkey-wrench mechanics.

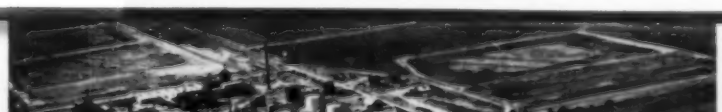


Tri-Non infrared analyzer construction features shown by removal of explosion-proof housings. Analyzer and associated sampling system in top unit; electronic accessories below.

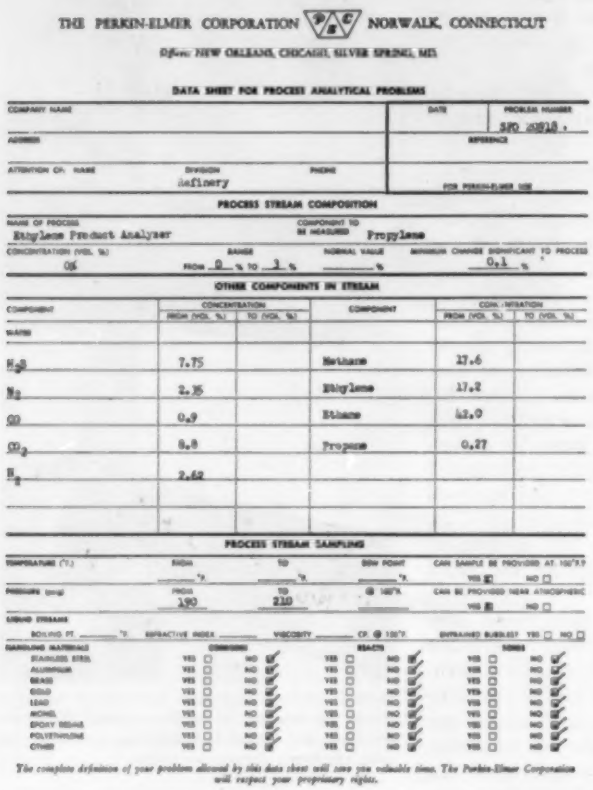
process control

Selecting an Analyzer

When one is selecting an analyzer for a given problem, the first step, of course, is to make sure that the particular analysis can be made by the instrument and that it has sufficient sensitivity to determine the component of interest in the range of concentrations expected. Next in importance is reliability. When a laboratory instrument breaks down, analyses may pile up, but there are usually other analytical methods that can take up the slack. When



Aerial view of the chemical plant



THE PERKIN-ELMER CORPORATION NORWALK, CONNECTICUT

Offices: NEW ORLEANS, CHICAGO, SILVER SPRING, MD.

DATA SHEET FOR PROCESS ANALYTICAL PROBLEMS

COMPANY NAME — DATE — PROBLEM NUMBER: SPD 10918

ADDRESS — REFERENCE

ATTENTION OF: NAME — DIVISION: Refinery — PHONE — FOR PERKIN-ELMER USE

PROCESS STREAM COMPOSITION

NAME OF PROCESS: Ethylene Product Analyzer — COMPONENT TO BE MEASURED: Propylene

CONCENTRATION (VOL. %)	RANGE	NORMAL VALUE	MINIMUM CHANGE SIGNIFICANT TO PROCESS
0%	FROM 0 % TO 3 %	%	0.1 %

OTHER COMPONENTS IN STREAM

COMPONENT	CONCENTRATION FROM (VOL. %)	CONCENTRATION TO (VOL. %)	COMPONENT	CONCENTRATION FROM (VOL. %)	CONCENTRATION TO (VOL. %)
WATER					
H_2S	7.75		Methane	27.6	
N_2	2.35		Ethylene	17.2	
CO	0.9		Ethane	42.9	
CO_2	8.8		Propane	0.27	
H_2	2.62				

PROCESS STREAM SAMPLING

TEMPERATURE (°F.): RANGE °F. TO °F. DEW POINT °F. CAN SAMPLE BE PROVIDED AT 150°F? YES ☑ NO ☐

PRESSURE (psig): RANGE 190 TO 210 @ 150°F. CAN BE PROVIDED NEAR ATMOSPHERIC? YES ☑ NO ☐

LIQUID STREAMS: BOILING PT. °F. REFRACTIVE INDEX VISCOSITY CP. @ 100°F. ENTRAINED BUBBLES? YES ☐ NO ☐

SAMPLING MATERIAL	CORROSIVE	REACTS	SOLIDS
STAINLESS STEEL	YES ☐ NO ☑	YES ☐ NO ☑	YES ☐ NO ☑
ALUMINUM	YES ☐ NO ☑	YES ☐ NO ☑	YES ☐ NO ☑
GLASS	YES ☐ NO ☑	YES ☐ NO ☑	YES ☐ NO ☑
GOLD	YES ☐ NO ☑	YES ☐ NO ☑	YES ☐ NO ☑
LEAD	YES ☐ NO ☑	YES ☐ NO ☑	YES ☐ NO ☑
MONEL	YES ☐ NO ☑	YES ☐ NO ☑	YES ☐ NO ☑
EBONY RESINS	YES ☐ NO ☑	YES ☐ NO ☑	YES ☐ NO ☑
POLYETHYLENE	YES ☐ NO ☑	YES ☐ NO ☑	YES ☐ NO ☑
OTHER	YES ☐ NO ☑	YES ☐ NO ☑	YES ☐ NO ☑

The complete definition of your problem allowed by this data sheet will save you valuable time. The Perkin-Elmer Corporation will respect your proprietary rights.

GUARANTEES

SUSPENDED SOLIDS? YES ☐ NO ☑ APPROX. LOAD/CU. FT. PARTICLE SIZE

LIQUID DROPLETS? YES ☐ NO ☑ IF NECESSARY CAN SAMPLE BE DILUTED? YES ☑ NO ☐

MISCELLANEOUS

RESPONSE TIME DESIRED 30 SECS. SAMPLE TIME LAG TO ANALYSER 30 SECS.

HOW IS SAMPLE TO BE VENTED? to atmosphere

PERKIN-ELMER TO PROVIDE FINAL PORTION OF SAMPLING SYSTEM? YES ☐ NO ☑

PAST ANALYSES HISTORY METHOD Mass Spectrometer

DIFFICULTIES too much time lag and lab overloaded

IF MULTIPLE STREAMS HOW MANY? DESIRED TIME CYCLE SECS.

DO YOU HAVE AVAILABLE STANDARDIZING MIXTURES? YES ☑ NO ☐ PURE N_2? YES ☑ NO ☐

INSTALLATION AND ENVIRONMENT

AMBIENT TEMPERATURE: 0 °F. TO 120 °F. AMOUNT DESIRED: MANUAL ☑ PNEUMATIC ☐

CORROSIVE ATMOSPHERE? YES ☐ NO ☑ EXCESSIVE VIBRATION AT ANALYSER SITE? YES ☐ NO ☑

AVAILABLE POWER: 110 VOLTS/C: 10 VOLTS, 60 CYCLES/C: 1/2 CYCLES. GOOD GROUNDS AVAILABLE? YES ☑ NO ☐

HAZARDOUS LOCATION: Class — Group — Division

ANALYSER 1 D 1

RECORDER non hazardous

DISTANCE ANALYSER TO RECORDER: 50 FEET

RECORDERS

STRIP CHART ☐ ROUND CHART ☑ PNEUMATIC CONTROLLER ☐ MULTI POINT, HOW MANY POINTS?

STANDARDIZATION: MANUAL ☐ SEMI-AUTOMATIC (MANUALLY-INITIATED) ☑ FULLY AUTOMATIC ☐

ALARM CONTACTS: HIGH ☐ HOW MANY? LOW ☐ HOW MANY?

SPECIAL REQUIREMENTS:

DO YOU HAVE TECHNICIANS FAMILIAR WITH ELECTRONIC-TYPE RECORDERS? YES ☑ NO ☐

MATERIAL AVAILABLE FROM PURCHASER

INFRARED SPECTRA? YES ☐ NO ☑ PURE COMPONENTS? YES ☑ NO ☐ ANALYZED MIXTURES? YES ☑ NO ☐

PLEASE ATTACH DIAGRAM AND FURTHER COMMENT IF NECESSARY

Actual data sheet after use by process plant to provide instrument manufacturer with essential information. Names blanked out.

a process stream analyzer ceases to function, however, an entire process may be forced to shut down. Hence, long-term stability and reliability are essential characteristics.

Any instrument requires some servicing, so serviceability is the next characteristic of importance. Some instruments are constructed with readily removable units and with built-in circuit testers. This greatly facilitates maintenance since faulty units may be quickly replaced and taken back to the shop for repairs. On stream down time is thus reduced to a minimum and extensive repairs need not be made in hazardous areas. The other aspect of serviceability is the facilities of the manufacturer of the instrument. They should be extensive, with overnight availability of service men and repair parts.

Finally, there is the matter of cost. Analyzers of all types range in price from $2,000 to $8,000–usually plus installation and any special sampling equipment required. When the total cost of instrument plus installation, plus special equipment, plus maintenance is weighed against savings resulting from improved processing efficiency, the basic instrument cost becomes relatively insignificant. Maintenance of a lesser quality instrument may more than eat up the price difference between it and the best quality equipment in less than a year's time. Thus, price should not be the main consideration in purchasing an analyzer.

Setting Up the Project

When the chemical engineer has decided that process stream analyzers will be of benefit to his process, he has essentially three courses of action available to him:

(1) If he has the proper analytical and instrument facilities available to him, he can take the "do it yourself" approach. With the assistance of the groups within his company, he can evaluate his process, select the analytical methods and instruments, construct the sampling systems and carry out the installation of the whole system.

(2) He can take the middle course of dividing the effort between himself and the instrument company. He can determine the analyses he wishes to make on a continuous basis and, submit a detailed description of the stream conditions, concentration ranges, desired accuracies, etc. to one or more instrument companies. When evaluating the resultant quotations he should compare carefully the statements concerning installation, the provision of auxiliary sampling equipment as well as the characteristics of the instruments quoted upon, and the facilities of the manufacturers. This second course of action is the one most generally used today.

(3) The final approach is "the systems approach "where the entire project is put in the hands of an instrument company. Several companies are equipped to carry out the whole job of evaluating the process, recommending the proper analytical points and the necessary instrumentation, as well as carrying out the assembly of components and the actual installation. Some companies will go a step further and provide the necessary computer systems that connect the analyzers to the environmental controllers and thus make the process completely automatic.

Incidentally, instrument companies are usually quite willing to respect confidences and to cooperate to the fullest degree with operating company personnel.

Thus this relatively new field of continuous analytical control is worth serious study by every chemical processing company. Much of the equipment and technical knowledge necessary to "automate" many processes–both old and new–already exist. The chemical companies and the instrument makers need only to pool their talents to put these new concepts to work.

Aerial view of the chemical plant of Celanese at Bishop, Tex., which illustrates the numerous columns needed to purify for sales the products derived from the partial oxidation of hydrocarbons.

how CELANESE separates its COMPLEX PETROCHEMICAL MIXTURES

W. C. Hopkins | Clarkwood, Texas
J. J. Fritsch | Bishop, Texas
Celanese Corporation of America

Recently, petrochemical plants based on the partial oxidation of hydrocarbons have been built by the Celanese Corporation at Bishop and Pampa, Texas, and by its affiliate, the Canadian Chemicals Company at Edmonton, Alberta, Canada. To a large extent, these plants owe their economic existence to azeotropic and extractive distillations.

Azeotropic and extractive distillations are almost as old as the organic chemical industry itself. In 1908 Emile Guillaume patented an extractive distillation to remove fusel oil from fermentation alcohol (*4*), and benzene azeotropic distillation to dry ethyl alcohol has been used for many years. In spite of their usefulness, these operations were almost neglected for a long time, and only in the past two decades have chemical engineers found widespread applications of azeotropic and extractive distillation. In the early 1930's the petroleum industry began to find uses for extractive distillation to separate paraffinic hydrocarbons from olefins and to separate aromatics from nonaromatics.

The recovery of pure chemicals from the crude product of the partial oxidation process involves complex separations which cannot be performed by ordinary distillation methods. The problems are best understood by considering the nature of the crude product. The major components are paraffinic alcohols, aldehydes and ketones, and the minor components are oxides, acids, esters, acetals, formals, and unsaturated oxygenated compounds. These chemicals are removed from the reaction system by water absorption, and the crude product, therefore, must be separated from an appreciable amount of water. From this complex mixture numerous pure products must be recovered, and each must meet rigid specifications in which tolerable impurities are often measured in tenths or even thousandths of one per cent.

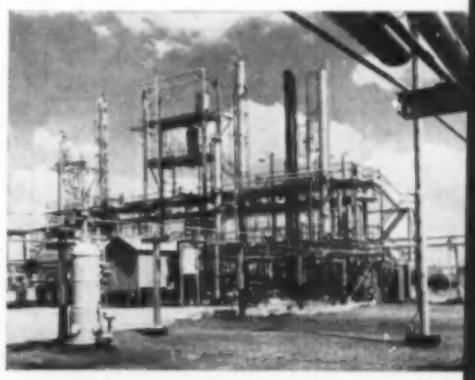
Some compounds in the crude product are grouped together with small differences in boiling points. Examples of such groups are as follows:

	Normal Boiling Point, ° C.
Propionaldehyde	48.8
Acrolein	52.5
Ethyl acetate	77.1
Methyl propionate	79.7
Propyl formate	81.3
Allyl alcohol	96.6
n-Propyl alcohol	97.8
sec-Butyl alcohol	99.5

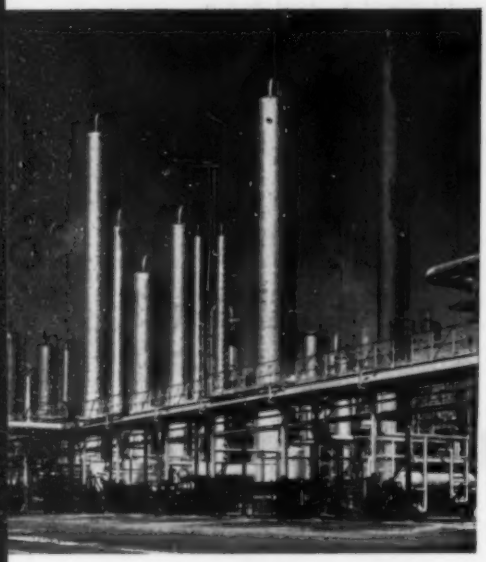
Close boiling compounds such as these are usually members of the same homologous series and are, therefore, nearly ideal systems. Straight fractionation to recover a pure product from one of these groups is not practical because too many plates would be needed.

The problems arising in the separation of close boiling ideal mixtures assume minor proportions when compared to the problems of nonideal azeotropic mixtures. A typical hydrocarbon reaction product contains more than forty components which are capable of forming more than fifty binary azeotropes with each other. Several ternary azeotropes are also known to exist and these are probably a small fraction of the ternary systems which are yet to be discovered. The azeotropes of eleven of the oxidation products, namely water and the saturated alcohols and ketones containing from one to four carbon atoms, are listed in Table 1. The azeotropes and the pure compounds are arranged in order of increasing boiling points. This list represents about one quarter of the possible constant boiling mixtures of a crude reactor product. An examination of Table 1 shows that the isolation by straight fractionation of any one product from a mixture of the eleven compounds is out of the question. All the methyl ethyl ketone, for example, might azeotrope with methanol at 64° C., and a cut made at 80° C., the boiling point of methylethyl ketone, might contain only tertiary butyl alcohol, isopropyl alcohol, and water.

Fortunately most of the close boiling or azeotropic compounds exhibit the differences in polarity which are required for the successful application of azeotropic and extractive distillation. Because of dissimilarities in molecular structure, the homologous groups of oxidation products can be arranged in



Pilot plant in the Clarkwood, Tex., plant of Celanese showing columns used for piloting plant distillations.



Section of purification unit at chemical plant of Celanese at Bishop, which includes extractive distillation columns.

order of increasing polarity. Such an arrangement previously given by Carlson *et al.* (*2*) has been expanded as follows:

Esters
Oxides
Aldehydes
Ketones
Acetals
Alcohols

In any one group, the compounds of lower molecular weight are more polar than the higher members of the series; straight chain molecules are more polar than those with branched chain structures; and olefinic compounds are more polar than the corresponding paraffin derivative.

Both azeotropic and extractive distillations use an entrainer or solvent to alter the relative volatility of the feed components. As Robinson and Gilliland (*10*) pointed out, the direction in which the relative volatility is changed depends upon the polarity of the solvent. If the solvent is a highly polar compound, the volatility of the more polar component is lowered, and the less polar compound is taken overhead. If a nonpolar solvent is used, this volatility relationship is reversed and the component with higher polarity is recovered as overhead product. This principle is a valuable aid in the preliminary search for a suitable solvent. Theoretically, it is possible to make a given separation with either a polar or a nonpolar solvent, but in practice it is desirable to select a solvent which will work in the same direction as the natural volatility of the key components, either by azeotrope formation or suppression of the volatility of the higher boiling compound. For example, methylal, the acetal of formaldehyde and methanol, forms an azeotrope with methanol which boils at 41.8° C. Methylal, with a b.p. 42.3° C., is much more volatile than methanol which boils at 64.7° C., and as is shown in the above table, methanol is more polar than methylal. An extractive distillation to break the azeotrope therefore requires a polar solvent to suppress the volatility of methanol. It has been found that the separation can be made with as little as 30 wt. % H_2O, a polar solvent, on the trays of the extractive distillation tower (*6*). Methylal is taken overhead and methanol and water are removed from the base. Methanol is easily recovered from the water by distillation in a second tower. For a nonpolar solvent to be effective in this separation, the normal volatility of the feed components would be completely reversed and methanol would come overhead. In theory this is possible, but the required solvent concentration would be too high for practical application.

Table 1.—Boiling Points of Selected Oxygenated Chemicals and Their Binary Azeotropes (*5*)

Pure Compound or Binary Azeotrope	Normal Boiling Point, ° C.
Acetone, methyl alcohol	55.5
Acetone	56.5
Methyl alcohol, methyl ethyl ketone	63.5
Methyl alcohol	64.7
Methyl ethyl ketone, water	73.4
Ethyl alcohol, methyl ethyl ketone	75.7
Methyl ethyl ketone, isopropyl alcohol	77.9
Ethyl alcohol, water	78.2
Ethyl alcohol	78.4
Methyl ethyl ketone, *tert*-butyl alcohol	78.7
Methyl ethyl ketone	79.6
tert-Butyl alcohol, water	79.9
Isopropyl alcohol, water	80.3
Isopropyl alcohol	82.5
tert-Butyl alcohol	82.9
n-Propyl alcohol, water	87.0
sec-Butyl alcohol, water	87.5
Isobutyl alcohol, water	89.8
Water, *n*-butyl alcohol	92.7
n-Propyl alcohol	97.8
sec-Butyl alcohol	99.5
Water	100.0
Isobutyl alcohol	108.0
n-Butyl alcohol	117.5

When close boiling compounds are to be separated, the relative volatility is almost unity, and the polarity of the solvent is not too important. The normal volatility of *n*-propyl alcohol relative to allyl alcohol is 0.94, but in the presence of water this relative volatility is greater than 1. A virtually complete separation of *n*-propyl alcohol and allyl alcohol is possible on a 60-tray extractive distillation tower with 75 wt. % H_2O on the trays (*8*). *n*-Propyl alcohol is the overhead product even though it is the least volatile component in a nonaqueous mixture.

It is necessary often to use both ex-

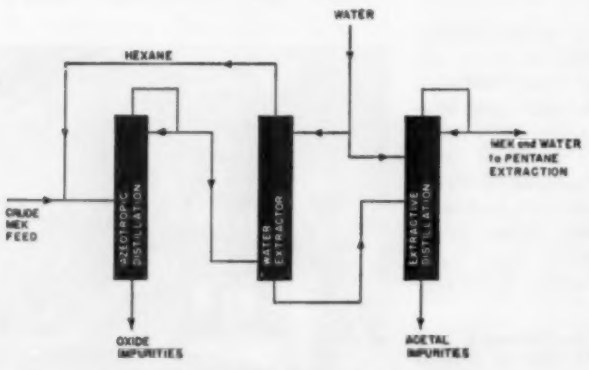


Fig. 1. Methyl ethyl ketone purification process.

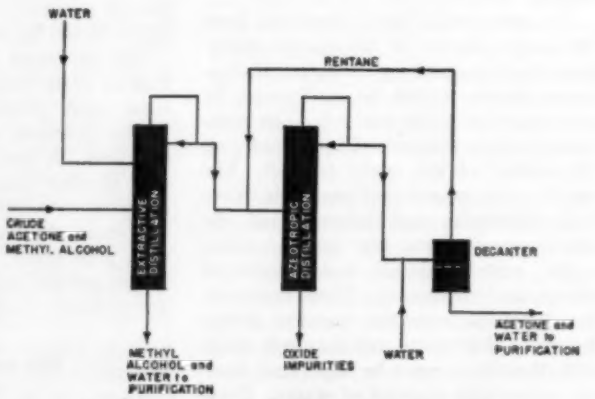


Fig. 2. Acetone, methyl alcohol separation process.

tractive and azeotropic distillation in a sequence of operations to recover a pure product from a crude fraction. For example, part of the methyl ethyl ketone produced from the partial oxidation of aliphatic hydrocarbons can be separated into a cut, containing methyl ethyl ketone and the impurities, methyl-tetrahydrofuran, formals, and acetals. The sequence of steps used to recover methyl ethyl ketone from this mixture is shown in Figure 1. An azeotropic distillation with *n*-hexane is used to remove all but a small portion of the impurities. The azeotrope is taken overhead at 65° C., and the *n*-hexane is removed by water extraction. The remaining impurities, acetals, are removed by a water extractive distillation with a solvent concentration on the trays of approximately 60 wt. %. The polar solvent, water, suppresses the acetals, and the azeotrope of methyl ethyl ketone and water is removed overhead (*7*). The methylethyl ketone is then dried by a method of pentane extraction.

Polar and nonpolar solvents can be used also in a series of steps to purify acetone and methanol. A ternary azeotrope of acetone, methanol, and tetramethylene oxide, a cyclic ether, is encountered in separation of partial oxidation products and can be broken by an extractive distillation with the use of the highly polar solvent, water. The relative volatility of methanol is lowered to the extent that the azeotrope of acetone and tetramethylene oxide may be distilled overhead in the extractive distillation column. This azeotropic mixture of acetone and tetramethylene oxide is separated by the formation of the lower boiling azeotrope of pentane and acetone boiling at 32° C. The acetone is further purified by extraction and distillation. The methanol taken out of the base of the extractive distillation tower is purified by conventional distillation (*1*). A schematic drawing of this purification process is shown in Figure 2.

In another example, polar and nonpolar entrainers are combined in one tower to separate close boiling compounds. The normal volatility of *n*-propyl alcohol relative to *sec*-butyl alcohol is 1.09. Separation of these close boiling compounds can be effected by an azeotropic distillation employing a ternary azeotrope (*9*). A ternary azeotrope of *n*-propyl alcohol, water, and methylcyclohexane is formed upon addition of a four to one ratio of water to methylcyclohexane to the fraction containing the *n*-propyl and *sec*-butyl alcohols. Separation of the overhead is simplified by the formation of two layers, a desirable solvent property in azeotropic distillation. The disadvantages of the solvents employed are (a) the high latent heat of vaporization of water, and (b) the complicated separation of the water and the *n*-propyl alcohol which themselves form an azeotrope. More than 90% of the *n*-propyl alcohol can be recovered by this method.

View of part of the alcohol purification unit where heavy alcohols are purified by ordinary and azeotropic distillation at the chemical plant of Celanese at Bishop.

Solvent selection is based not only on its polarity and its ability to alter relative volatility, but also on its cost, stability, noncorrosiveness, and nontoxicity. In addition, the ease of separating the solvent from the desired product, and the latent heat of vaporization of the solvent must be considered in azeotropic distillation problems. Vapor-liquid equilibrium data, which cover a broad range of concentrations of the selected solvent and the key components, are used to determine the optimum solvent concentration and the optimum reflux ratios and number of trays to be used in the design of an efficient tower. Solvent concentration is a variable in extractive distillation, while the solvent concentration on the trays is necessarily limited in azeotropic methods and can only be varied by changing solvents and to a minor extent by changing pressure on homogeneous azeotropes.

Because of the complex nature of many of the mixtures, it is usually wise to check a calculated design in a pilot plant operation before a commercial installation is made. In fact, some of the towers for the azeotropic and extractive distillations encountered in a hydrocarbon oxidation plant must be designed entirely from pilot plant data. The purification of aqueous formaldehyde solutions is a good example of such a case. Formalin produced by the partial oxidation of hydrocarbons contains, even after several distillations, impurities which are present in minute quantities. These impurities, which cannot be detected by direct analysis, make their presence known by their adverse effect on certain product specification tests such as residual odor and the development of color with sulfuric acid treatment. The amount of these impurities is too small to permit quantitative analysis, and so basic equilibrium data are impossible to obtain. Separations such as these are developed entirely in laboratory and pilot plant columns. Optimum solvents and operating conditions are evaluated by finding the effect of each of these as a variable on specification tests of the finished product. The problem of purifying formalin was approached in this manner, and it was found that an extractive distillation with a polar solvent such as ethylene glycol would carry the impurities out of the base of the tower. The formalin product which was taken overhead passed the critical specification tests (*3*).

It is thus apparent that a partial oxidation plant has many practical applications of azeotropic and extractive distillation. Searches for new applications of these operations do not end with the design and construction of a new plant. A continuing study of purification problems easily pays for itself by revealing more efficient methods for isolating old products and by showing how new products can be recovered from mixtures previously considered worthless.

distillation

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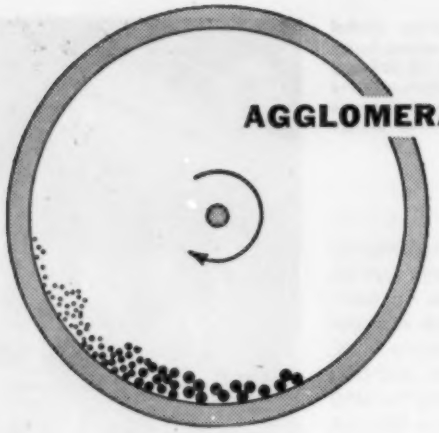

AGGLOMERATING

iron ore concentrates

The experience with materials described below may suggest useful techniques for other applications—*Editor*

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Because of the rapid depletion of high-grade iron ore reserves in the Great Lakes area, mining companies have been seeking iron-bearing materials from low-grade ores, particularly from the taconites. However, many problems originate in the beneficiation of these ores, not the least of which is the unsuitability of the fine concentrates produced by ore-dressing method as blast furnace raw material. To convert low-grade iron ore (mainly taconite) into a form which is consonant with the blast furnace, the fine material must be agglomerated in such a way that the product is relatively coarse, resistant to abrasion and impact, yet is easily reduced in the blast furnace.

Pelletizing is the technique of agglomerating described in this paper. Various other methods of agglomerating fine ores and concentrates into lump form have been developed in the past fifty years, but only three have become economically feasible: briquetting, sintering, and nodulizing.

Briquettes are produced by mixing then molding fine ore with binders. The process is not used in the United States today. Sinter is a porous clinker produced by mixing ore with coke or coal and then firing on a grate. Much fine ore from the eastern and western states and blast furnace flue-dust are sintered, but comparatively little Great Lakes ore has been so treated, except on an experimental scale. Nodulizing consists in passing fines through a rotary kiln at temperatures near the fusion point of some of the constituents, so that the material agglomerates into lumps. Taconite concentrates and fine ore are being successfully nodulized in a new plant in Minnesota (*2*).

Pelletizing is effected by rolling damp fine ore or concentrates in a drum then firing in a furnace or on a grate the green balls so produced. At present two large pilot plants in Minnesota are producing pellets from magnetic taconite concentrates, and large-scale plants are either being designed or are under construction for the production of pellets. Several, small experimental plants are in operation elsewhere, and at least one company has worked with balled concentrates in a nodulizing kiln and with mixed charges of balls and ore on grate-type sintering machines.

Development of Pelletizing

The first printed reference to the balling process was by Barrett (*1*), and the method was subsequently patented by Dean (*7*). The Mines Experiment Station of the University of Minnesota, under Davis, undertook an extensive investigation of the process as applied to fine iron ores, and a classic paper by Firth (*8*) appeared in 1944. In 1950 Tigerschiöld and Ilmoni described certain laboratory techniques in producing green balls and fired pellets and advanced an hypothesis to account for the strength of green balls (*10*). A number of iron mining companies have investigated extensively balling and pelletizing, but details of their research have not been made public.

The ore-dressing laboratories of the Minnesota School of Mines and Metallurgy have investigated the physicochemical mechanisms which produce high strength in fired pellets (*3, 4, 5*). In 1951 Davis and Wade described the practical aspects of pelletizing on a pilot plant scale (*6*).

FACTORS INFLUENCING BALLING

Apart from purely mechanical factors, those which appear to be the most important in balling are (a) the specific surface of the ore or concentrate as indicated by the size distribution of the particles, and (b) the nature and quantity of the additives which are incorporated prior to balling. To these possibly a third factor may be added (c) the mineralogical composition of the ore. In the succeeding pelletizing operation all three factors can be of importance, although under (b) some additives which confer high green strength exert a negligible effect on the properties of the fire pellet, and conversely, certain additives have no perceptible effect on the green balls but produce marked effects on the characteristics of the pellets.

Although balling is an intermediate step in the production of the pellets, its requirements are no less severe than the succeeding firing operation. Green balls must possess properties which will enable them to withstand handling and loading into the pelletizing furnace and also to maintain shape and coherency during the critical period when the contained moisture is removed in the furnace. Homogeneity in the green balls is highly desirable.

Table A.—Size Analysis of Concentrates

Size	Wt. %
28/48 mesh	0.36
48/65	0.27
65/100	0.50
100/150	1.25
150/200	4.43
200/270	8.30
270 mesh/34 microns	9.88
34/24	10.80
24/17	15.31
17/12	13.00
12/8.5	11.38
8.5/6	8.74
minus 6	15.78

(a) Specific Surface

The specific surface of a material must be high before balling can occur. Sand free from slimes will not ball, but inclusion of slimes will permit the process to function. Taconite concentrates have a fairly high specific surface as can be inferred from the size analysis shown in Table A.

Specific surface of a typical magnetic taconite concentrate, measured by the permeability method, amounts to about 2,000 sq.cm./g. and by the gas adsorption method to about 8,000 sq.cm./g. Pyrite calcine (ferric oxide) has a high specific surface and balls easily. Difficulty is experienced, however, in pelletizing specularite flotation concentrates, for these tend to be granular, and the difficulty is compounded by the necessity of desliming the ore prior to flotation. Davis and Wade (6) state that magnetic taconite concentrate must be practically all finer than 65-mesh and that 60% or more must pass a 325-mesh screen to effect satisfactory balling.

(b) Nature of the Additives

A considerable amount of work has been done on various additives which improve balling and which give a sturdier green ball than water alone, such as iron ore slimes, starch and starch products, and bentonite, but unfortunately the information acquired has not been published.

Some investigations have been made regarding strength vs. liquid content, and strength vs. amount of additive applied as a surface binder to green pellets.

Individual balls from any specific batch are remarkably similar with respect to moisture content and ultimate porosity. Thus ten pellets taken at random from a freshly prepared batch had moisture contents the average of which had a probable error of 1.7%. These pellets had a moisture content of 7.70% ± 0.09%. This same degree of uniformity applies to the percentage porosity of air-dried balls formed from a specific batch of green balls. In a test case the most accurate method of measuring porosity gave a value of 28.5% ± 0.3%, the average porosity of twelve air-dried pellets selected at random having a probable error of 1%. These closely reproducible values of moisture content and porosity from ball to ball probably account for the reproducible strengths for balls made from a specific batch and treated under identical conditions.

The so-called "wet strength" of a green ball is dependent upon the amount of original liquid retained by the ball. Figure 1 shows the strength vs. per cent of original water retained for two specific batches of balls originally containing 7.50 and 7.82% water. The strength increases rapidly as evaporation proceeds, reaching a maximum when 7 to 10% of the contained water has disappeared, thereafter gradually dropping to that of the air-dried ball. This may explain in part the relatively strong balls Tigerschiöld and Ilmoni obtained when they prepared them under conditions where appreciable evaporation of the contained moisture could occur (*10*).

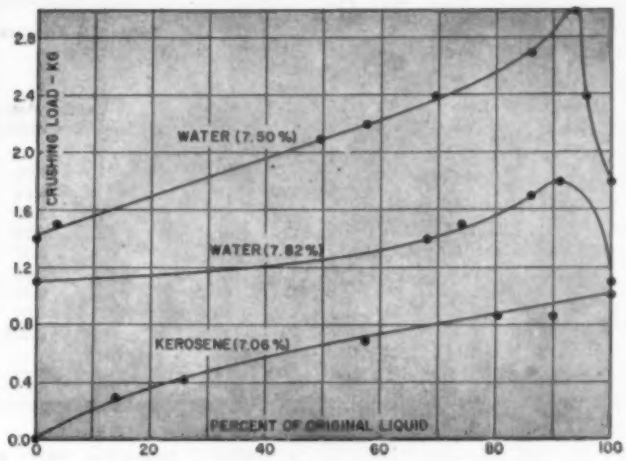

Fig. 1. Strength-drying curves for magnetite balls prepared with water and kerosene.

As shown by the lower curve of Figure 1, balls formed with a hydrocarbon medium such as kerosene did not exhibit this increase in strength, the maximum strength being at the original medium content. Balls made with kerosene have practically no dry strength, collapsing under their own weight when the liquid has entirely evaporated.

The dry strength of balls is undoubtedly induced by the water. When air-dried balls are fired under such conditions that all adsorbed or chemically bound water is removed the strength diminishes practically to zero.

Tigerschiöld and Ilmoni have shown (*10*) that there is a direct correlation between the crushing strength of a green ball and the capillary force, the last-mentioned being given by:

$$z = \frac{2a \times \cos i}{r \times \delta \times g}$$

in which

z = the capillary rise in cm.
a = surface tension in dynes/cm.
r = average pore radius
δ = density of liquid filling pores
g = acceleration due to gravity

The angle of contact is given by i, and for clean gangue and hematite particles this is zero degrees. However, if a collecting agent is used to float the hematite, i becomes finite. For a reasonable value of i, say 45°, z is only 0.7 of its value when i is zero, and the negative pressure within the pellet is diminished by about 40%. If the angle of contact is increased to 90°, which could be the case if hydrocarbon oils were used to assist flotation, then the capillary rise is zero, and the pellet should not hold together. In the case of certain specularites the situation is aggravated by the removal of slimes prior to flotation, but addition of material such as bentonite seems to take care of this situation.

In operation, additives other than water are normally incorporated with the ore between the filters and the balling drum. Because much of the strength of spheres subjected to crushing resides in the outer shells and because, other things being equal, bulk incorporation of additive costs more than a superficial layer of additive, the effect of adding surface coatings of starch and sodium

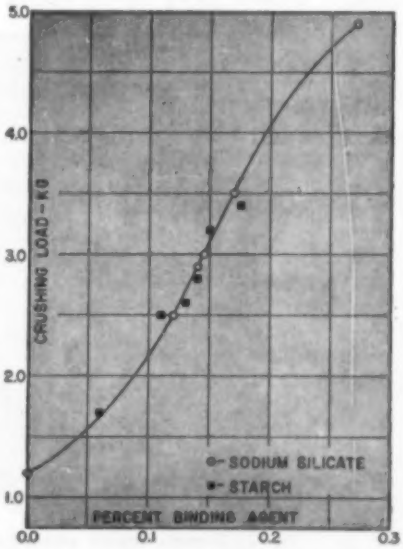

Fig. 2. Dry strength of magnetite balls vs. per cent of binding agent added superficially.

silicate solutions to dry balls was investigated.

If the reagents are sprayed as aqueous solutions directly on to the hot pellets, they tend to spall or peel off as dry films. This effect is successfully overcome by applying the reagents as a spray consisting of a suspension of fine magnetite concentrate in the solution of the reagent. Applied in this manner the reagents adhere to the surfaces readily and dry as layers, with no tendency to peel.

As shown in Figure 2, if the starch or silicate is added to the extent of 3 lb./ton of material, its binding effect increases the dry strength of the pellet by a factor of about 3, the increase between the limits of 0.05 and 0.20% of the reagent being proportional to the quantity of reagent added. For equivalent quantities there is no measurable difference in the binding quality of the two reagents.

Since the coatings are very hard, they make the dried ball quite resistant to abrasive action, and subsequent investigations show that they contribute little to the strengths of the fired pellets.

Reduction tests made on both coated and uncoated balls which were fired at 1,100° C. show a remarkable increase in reduction rate for balls coated with sodium silicate. These attain 80% of theoretical reduction in about 30 min., compared with 45 min. for the same per cent of reduction for uncoated balls.

(c) Mineralogical Composition of Ore

The present state of the art of balling ores does not permit conclusions regarding the effect of mineralogical composition upon the relative ease of balling.

Apart from the effect of additives, the specific surface has so preponderating an effect on the success or failure of balling, that any effect of mineralogical composition would seem to be relatively minor. It is conceivable, however, that a relatively small amount of finely divided hydrated minerals such as talc, clay, limonite, and possibly the amphiboles of the taconites may be important in producing balls of high strength.

Table 1.—Analyses of Materials Used in Pelletizing Tests

	% Composition			
	A Mesabi Magnetite Concentrate	B Eastern Magnetite Concentrate	C West African Specularite	D Mesabi Limonite
Fe (Total)	63.25	71.34	67.40	57.41
Fe^{++}	19.00	23.86	1.54	0.30
SiO_2	8.84	0.52	3.31	8.50
Al_2O_3	1.45	.....	.....	.....
CaO	0.08	.....	.....	.....
MgO	0.57	.....	.....	.....
TiO_2	0.08	.....	.....	.....
Mn	0.12	.....	.....	.....
S	0.01	.....	.....	.....
P	0.025	.....	.....	.....
H_2O	.....	.....	.....	7.86
Size (−325 mesh)	75.01	77.77	77.00	76.00

Production of Pellets by Firing Green Balls

From the preceding discussion it is apparent that specific surface, the nature and quantity of certain additives, and probably the mineralogical composition of the ore are important to the process of balling. These three factors are important also in the subsequent process of producing fired pellets from the green balls, and to them may be added two more, the firing temperature and the composition of the atmosphere in which the balls are fired.

As strength of the product has been considered one of its more important characteristics, this has been used as a criterion in the following work. It should be realized, however, that other criteria such as reducibility, abrasion, and shock resistance, and homogeneity in structure and mineralogical composition should be investigated.

To study the effects of some of the variables controlling hardness, green balls of four different materials were prepared by a standard laboratory procedure. The materials were (A) a magnetite concentrate produced from Mesabi taconite, (B) a high-grade Eastern magnetite concentrate, (C) a West African specularite, and (D) a Mesabi limonitic ore. Chemical analyses of these materials are given in Table 1.

Firing was conducted under various conditions, and strengths were determined by measuring the maximum crushing load the cooled pellets could withstand before rupturing, this being ascertained on an Amsler testing machine. Each point on the curves of strength represents the average crushing load of ten pellets.

(a) Effect of Firing Temperature, Atmosphere on Strength Isotherms

Mesabi magnetite balls (A, Table 1) were fired at constant temperature for various periods of time, a constant air stream amounting to 5 cc./(min.)/(g. of contained magnetite) being passed over the pellets during the tests. As shown in Figure 3, pellet strengths are a function of time and temperature. Strengths increase nearly linearly up to 30 min., and then gradually level off.

The results of increasing the air flow to 28 cc./(min.)/(g. magnetite), at 600° C., are also shown in Figure 3. A greater initial gain in strength is realized, but the ultimate strength is unaffected.

Magnetite oxidizes in air to form hematite, according to the following reaction (*9*).

$$2Fe_3O_4 + 1/2O_2 = 3Fe_2O_3;$$

$$\Delta H = -61{,}700 \text{ cal.}$$

This reaction occurs, for the most part, in a concentric spherical shell surrounding the core, and the heat is transferred inward to the core and outward to the surface. The heat transferred to the pellet surface is radiated to the surroundings at a rapid rate, and that trans-

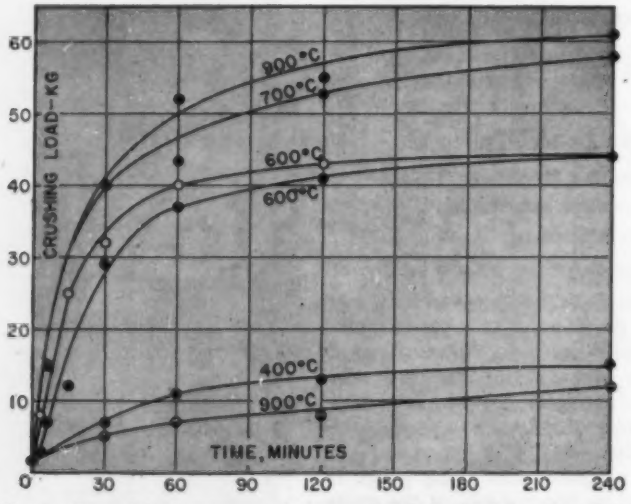

Fig. 3. Strength-isotherm curves for magnetite balls fired in air and in nitrogen. Black points, fired in air at 5 cc./(min.)/(g.); white points, fired in air at 29 cc./(min.)/(g.); white and black points, fired in nitrogen at 5 cc./(min.)/(g.).

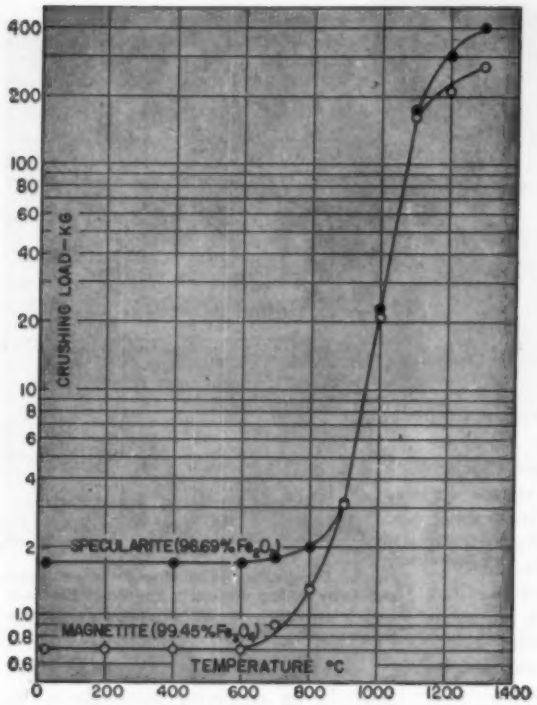

Fig. 4. Strength-temperature curves for balls of relatively pure specularite and magnetite fired in nitrogen for 30 min.

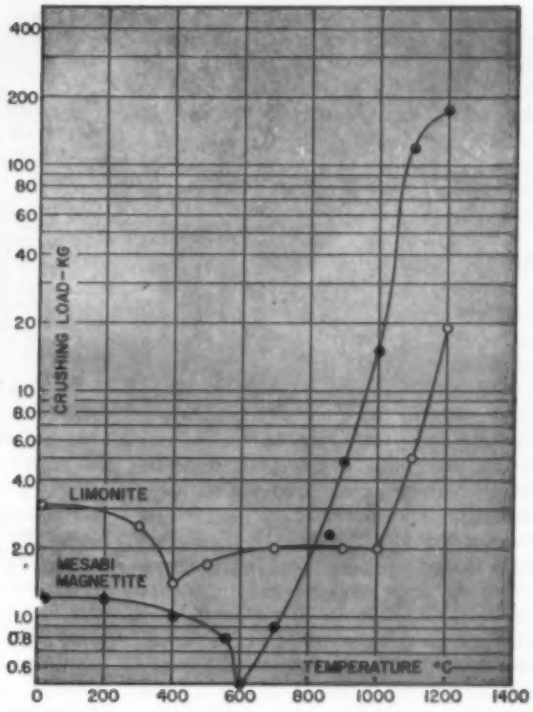

Fig. 5. Strength-temperature curves for balls of Mesabi limonite and Mesabi magnetite concentrates fired in nitrogen for 30 min.

ferred inward raises the core temperature. The completion of the exothermic reaction and the final equilibrium of heat transfer allow both the core and surface temperature to approach the temperature of the furnace. It has been shown elsewhere (*4*) that ¾-in. pellets fired below 1,000° C. attain furnace temperature within 30 min., when an airflow is used of 5 cc./(min.)/(g. magnetite). This quantity of air was adopted because it was a rate which theoretically would oxidize completely a 50-g. magnetite ball during a 30-min. firing period. This laboratory information on the rate of oxidation of magnetite balls is confirmed by pilot plant findings, which indicate that high strength is obtained in relatively short periods once the combustion of the magnetite has been initiated.

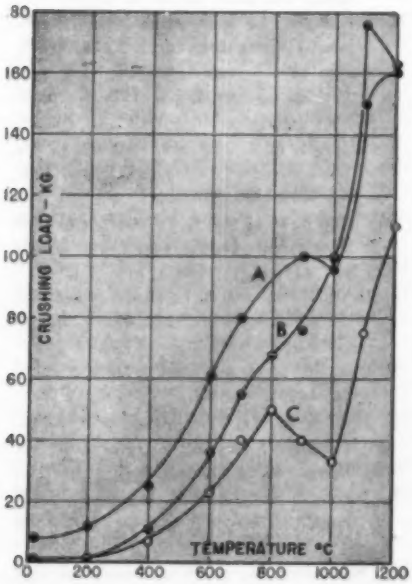

Fig. 6. Effect of type of additive on strength of magnetite balls fired for 30 min. in air at various temperatures: A. Mesabi magnetite concentrates with no additives; B. Mesabi magnetite concentrates with 5 lb./ton borax glass added; C. Mesabi magnetite concentrates with 10 lb./ton bentonite added.

The lowest curve in Figure 3 shows that the gain in strength obtained by firing magnetite balls in nitrogen at 900° C. is much less than when air is used.

In the succeeding tests pellets were fired for 30 min. in an atmosphere which was inert with respect to the iron oxides present, i.e., nitrogen for the magnetite and air for the hematite and limonite. Results of firing balls of the West African specularite and the Eastern magnetite are shown in Figure 4, in which the firing temperature is plotted against the pellet strength on a semilog scale. The results of firing Mesabi magnetite and Mesabi limonite balls are shown in a similar plot in Figure 5.

Below 700° C., pellets of specularite and Eastern magnetite show little or no increase in strength with temperature, but above this temperature a rapid increase is apparent, the thermal region of maximum increase in strength being between 900° and 1,100° C. Fracture surfaces of these pellets were hackly, dissimilar to the conchoidal fractures obtained from pellets containing appreciably more slag-forming constituents.

Limonite pellets fired at temperatures above 500° C. were prefired for 15 min. at 400° C., to prevent decrepitation caused by the rapid expulsion of combined water. Peculiar minima in strengths were obtained when balls of Mesabi magnetite and Mesabi limonite were fired at 400 and 600° C. respectively (Figure 5). This decrease in strength was accompanied by a rapid expulsion of combined or adsorbed water. Balls of the Mesabi magnetite and limonite which were air dried at room temperature contained 0.23 and 7.65% water respectively. The evolution of water from these pellets during 30-min. firing periods is given in Table B.

Table B

Mesabi Limonite		Mesabi Magnetite	
Temp. ° C.	% Total Water Removed	Temp. ° C.	% Total Water Removed
25 (room temp.)	0	25	0
100	14	100	42
300	26	200	46
400	99	400	62
500	100	600	93
		800	100

These data show that 73% of the water originally contained in the limonite balls was evolved between 300 and 400° C., and that 31% of the water in the magnetite concentrate balls was evolved between 300 and 600° C. It is within these same temperature limits that there occurs so marked a decrease in strength.

(b) Effect of Additives on Strength of Pellets

Organic additives such as starch and its derivatives may be added to balls to increase their green strength but they burn out during firing and, except for a small effect on porosity, have no other influence. On the other hand, additives such as lime, magnesia, bentonite, and borax may have a powerful influence on the strengths of fired pellets (*4*). Bentonite and borax have been used on a pilot plant scale for producing high-strength pellets. Coal is frequently added to both hematite and magnetite during balling, in the first case to convert hematite to magnetite in the earlier stages of firing and thus to utilize the strong bonding action of freshly created hematite during the later stages (*6*), and in the second case to raise firing temperatures.

Strengths of fired pellets made from Mesabi magnetite concentrate increase when either bentonite or borax glass is added during balling. Results of firing pellets containing ½% bentonite and ¼% borax glass as bulk additives are shown in Figure 6, in which strength is plotted against the corresponding firing temperature. The tests were made for 30 min. in an air stream of 5 cc./(min.)/(g. of magnetite). For comparison, the results of firing the same material free from additives are plotted in the same figure. The chemical analysis of the bentonite is given in Table C.

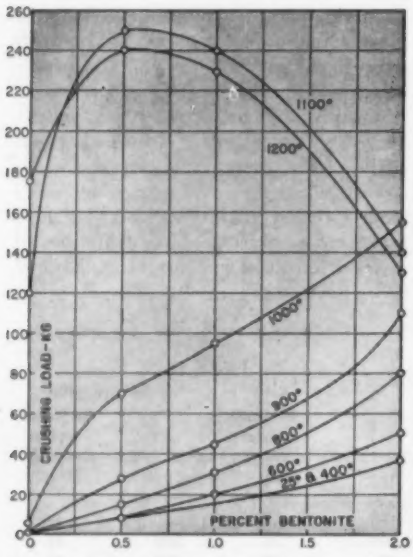

Fig. 7. Effect obtained on strength of magnetite pellets by adding various quantities of bentonite and firing for 30 min. in a neutral atmosphere and at different temperatures.

Table C.—Chemical Analysis of Bentonite

SiO_2	57.98%
CaO	1.92
FeO	0.12
MgO	3.24
Fe_2O_3	3.80
$Na_2O + K_2O$	1.35
Al_2O_3	22.46
SO_3	0.75
Ign. loss	7.93

The strength-temperature curves of fired pellets containing ½% bentonite follow the same trend as those of fired pellets of the ore alone, strengths for corresponding temperatures being much higher for the pellets containing bentonite. The drop in strength at 1,000° C. is caused by a duplex structure. The core, composed of magnetite in semi-fluid slag, separates to a large extent from the shell, which is composed of hematite, quartz, and silicates. This phenomenon is discussed at length elsewhere (*3*).

Pellets containing ¼% borax do not decrease in strength at either 900 or 1,000° C. Apparently the bonding influence of borax with hematite and magnetite is sufficient to overcome the decrease in strength caused by the duplex structure.

The dry strength of unfired balls containing up to 2% bentonite increases nearly linearly with the quantity of additive (see Figure 7, the 25° curve). Air-dried balls containing 2% bentonite have a crushing strength 31 times that of balls without binder. This increase in dry strength with bentonite addition is particularly important in the agglomeration of ores by methods which require balls of particularly high green strength.

The effects of the quantity of additive on the strengths of fired pellets of Mesabi magnetite concentrate are shown in Figures 7 and 8. The former shows the strength-temperature relationships of pellets containing up to 2% bentonite after firing for 30 min. in nitrogen. The latter shows the same relationships for pellets containing up to the same amount of bentonite after firing for 30 min. in air. The air was passed over the pellets at a rate of 5 cc./(min.)/(g. of magnetite).

The rapid decline in strength of pellets fired at 1,100 and 1,200° in nitrogen, and containing more than 1% bentonite is probably due to the formation of excessive quantities of slag. Such pellets, when crushed, break into several large pieces having glassy, conchoidal fractures. Pellets containing bentonite and fired at various temperatures up to

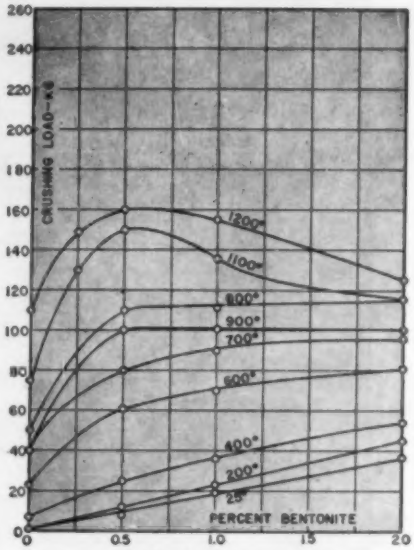

Fig. 8. Effect obtained on strength of magnetite pellets by adding various quantities of bentonite and firing in air for 30 min. at different temperatures.

800° in an oxidizing atmosphere, increase in strength with both increase in temperature and increase in additive. However, as the firing temperature approaches 800°, the effect of quantity of additive in excess of 0.5% is not very marked, and above this temperature the maximum strength is given by 0.5% bentonite.

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Presented at A.I.Ch.E. meeting, Glenwood Springs, Colo.

Aerial view of Yerington plant with sulfuric acid plant and FluoSolids System in center. Primary and secondary crushing is carried out in the building at the upper left.

Anaconda's Yerington Plant Demonstrates ECONOMICAL RECOVERY OF sulfur from low-grade ore

R. B. Thompson and Donald MacAskill | Dorr-Oliver Incorporated, Stamford, Connecticut

In the latter part of 1950 the sudden world shortage of elemental sulfur posed to those industrial organizations requiring large quantities of sulfuric acid the possibility of curtailed productivity. This situation has been eased somewhat in the past three years both by the discovery of vast new supplies of elemental sulfur and by the FluoSolids roasting of metallic sulfide ores to produce sulfur dioxide gas.

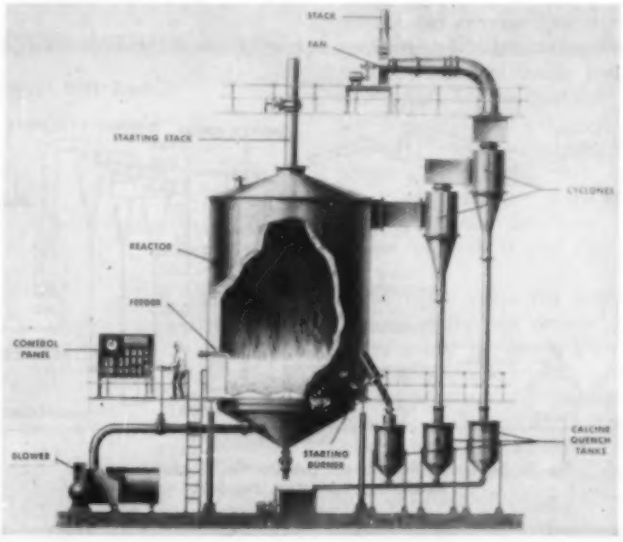
Almost simultaneous with the sulfur shortage, the United States Government, desiring to maintain adequate copper reserves, contacted Anaconda Copper Mining Company to determine whether any undeveloped copper properties could be put into operation. Anaconda agreed to reopen the ore body near Yerington, Nevada, which had been mined periodically from 1870 to 1930 by other organizations and on which Anaconda started prospecting in 1942. The government also requested that Anaconda develop, if possible, its own source of sulfur to be used in the production of 450 tons/day of sulfuric acid for leaching of the oxide ore. It is the purpose of this paper to describe a fluidizing-type roaster which is being used to oxidize a low-grade sulfur ore to sulfur dioxide for the production of sulfuric acid. This is shown schematically in Figure 1.

Among the possible sulfur sources for the Yerington operation was the vast Leviathan deposit of low-grade sulfur ore in Alpine County, California, just fifty-eight miles from the proposed plant site. This body had been worked only occasionally in previous years because no means had been developed to recover economically the contained sulfur. Anaconda engineers, familiar with a pilot plant FluoSolids system used for research investigations at Anaconda, Montana, recognized the possibility of roasting Leviathan ore to produce sulfur dioxide for contact acid manufacture. Based on both laboratory work by The Dorr Company (now Dorr-Oliver Incorporated) and pilot plant testing by Anaconda in a 7-ton/day unit, a commercial plant was designed and has been in operation for about one year.

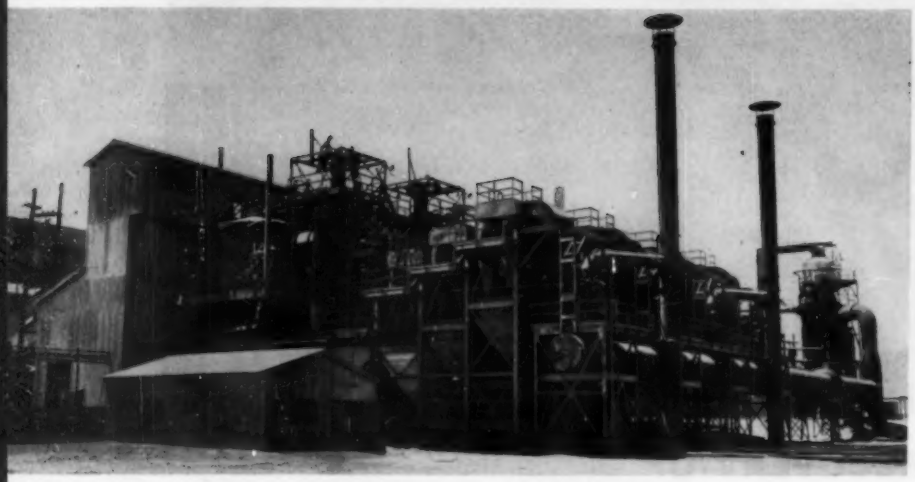
Table 1 gives an analysis of the Leviathan ore. The mineral content is approximately 84% Andesite and 16% Tufa, both rather heavily impregnated with elemental sulfur. In addition the ore also contains minor amounts of pyrite.

The pilot plant investigation had demonstrated that this ore could be successfully roasted in a fluid bed at temperatures from 1,200 to 1,600° F. Design of the commercial unit was based on the −10-mesh ore fluidized at a superficial gas velocity of 1.7 ft./sec. Approximately 70% excess air resulted in high yields of sulfur as sulfur dioxide and a suitable gas–12% SO_2–for conversion to sulfuric acid by a contact acid plant.

In order to realize the commercial potential of this research work, The Dorr Company supplied Anaconda with a FluoSolids system which was put in operation in October, 1953.



Raw ore is roasted in four cylindrical reactors, 25 ft. high and 18 ft. I.D. Heat loss is minimized by a 4½ in. wide innermost layer fire



Closeup of DorrCo. FluidSolids System.

brick surrounded by a 9-in. layer insulating brick. A welded steel shell encloses the entire unit. Each reactor roasts slightly more than 200 tons of ore/day, but only three reactors are in operation at one time with the fourth being kept in reserve. Daily plant capacity averages 650 tons of ore or 450 tons of 100% H_2SO_4.

Figure 2 is a vertical cross-section of one of the FluoSolids reactors. Provision was made for a 5-ft. depth fluid bed regulated by the overflow nozzle. Raw ore, after being dry crushed in rod mills, is fed through the opening in the top of each reactor and drops by gravity through the freeboard onto the fluid bed where most of the roasting takes place.

Table 1.—Approximate Analysis of Leviathan Ore

	%
Total sulfur	30
Elemental sulfur	25
Insolubles	55
Iron	5.5
Copper	0.4
Moisture	7.0
Specific gravity	2.1

Fluidizing air is distributed through a horizontal, perforated plate fitted with a number of stainless steel nozzles. These nozzles serve to distribute the air over the reactor area and also prevent the back flow of solids. Normal feed rate of 9 tons of ore/(reactor)/(hr.) requires 8,000 cu.ft./min. of air at 3 lb./sq.in. This includes approximately 75% air in excess of that necessary to convert all the sulfur to sulfur dioxide and to convert the iron to iron oxide. The blowers, each capable of supplying a maximum of 13,000 cu.ft./min., are of the positive displacement type and are equipped with snubbers to even out pulsations and reduce noise. Air flow is measured by a ring balance meter with automatic compensating features to adjust for atmospheric temperature and pressure changes.

Temperature averages 1,200° F. in the fluid bed, although satisfactory operation has been experienced at temperatures from 1,000 to 1,400° F. Freeboard temperature runs 50 to 100° F. above that of the bed. With a 5-ft. fluid depth, detention time in the reactor is approximately 5½ hr. In the initial start-up, or after a prolonged shutdown, the bed is brought up to temperature with the use of propane-burning preheaters. These burners are employed until a temperature of 900° F. is attained at which time feeding of sulfur ore is commenced. During a shutdown of several days' duration, the static bed of solids will retain a sufficient amount of heat (a bed temperature of 900° F. or higher) to permit restarting merely by resuming feeding and starting the air blower.

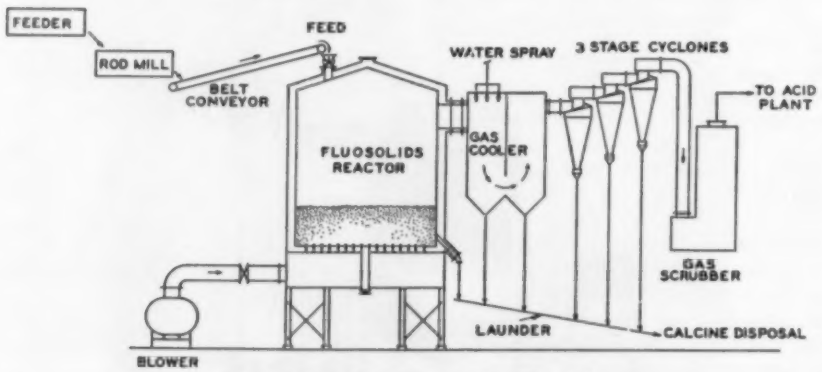


Fig. 1. Schematic flow sheet. The DorrCo. Fluosolids system, Anaconda, Yerington, Nevada.

Whereas the design of these reactors had contemplated an ore crushed to −10-mesh, in actual practice it was discovered that the FluoSolids units would have to handle a much coarser feed. The crushed ore, rod mill discharge, which goes directly to roasting has contained up to 25% + 10-mesh material. Screen analyses of feed to the system at three different times during initial operation are shown in Table 2.

The presence of these coarse pieces of ore was soon noticed in the fluid bed. As is normal for fluidized solids beds, initially there was no detectable temperature gradient within the bed. However, it was soon noticed that as operation continued, the lower sections of the bed showed temperatures considerably lower than the upper layers. Apparently the coarser fractions of the feed solids were segregating on the bottom of the reactor. If allowed to continue, the entire bed would become static or defluidized, and the units would be inoperable. An active, fluidized bed is essential to provide the mixing and heat transfer required for the reaction. To correct this situation the solid product from the fluid bed was withdrawn near the bottom instead of at the top, as originally contemplated. With a Dorrco FluoSeal valve to seal against the reactor pressure, the discharge rate is regulated manually to maintain the fluid bed depth between 4 and 5 ft. as indicated by the pressures within the reactor. This change in point of draw-off has proved to be entirely satisfactory and has enabled the FluoSolids reactors to handle the much coarser ore without trouble.

Sulfur dioxide bearing gas from each FluoSolids reactor passes directly into a two-compartment cooler in which twenty high-pressure water sprays cool the gas from 1,200 to 800° F. From the cooler the gas stream passes through three stages of mild steel cyclones which remove about 92% of the entrained solids. Each stage consists of four cyclones in parallel—a total of twelve cyclones per reactor or forty-eight in all. The gas—26,000 to 28,000 cu.ft./min. of 12% SO_2—is further cleaned and cooled to 100° F.

in a wet scrubber before it goes to the sulfuric acid plant.

Solids from the reactor and the dust from the three stages of cyclones are quenched in spent solution from the cementation plant and discharged to a calcine dump in the desert. Table 3 indicates the distribution of the calcined solids from one reactor in two instances during the period of initial operation in October and November, 1953.

The material discharged as a solid product from the fluid bed amounts to 20 to 25% of the total calcine and contains about 0.5% total S; it is 99% coarser than 100-mesh (Table 4). With the coarser feed (Case 3, Table 2) the product discharged from the fluid bed amounts to 45 to 50% of the total calcine. The remainder of the product is taken out after roasting in the gas cleaning equipment. Sulfur content of the cyclone discharge products analyzes 1.2% S. The total recovery of sulfur from ore to sulfur dioxide is 98% or better.

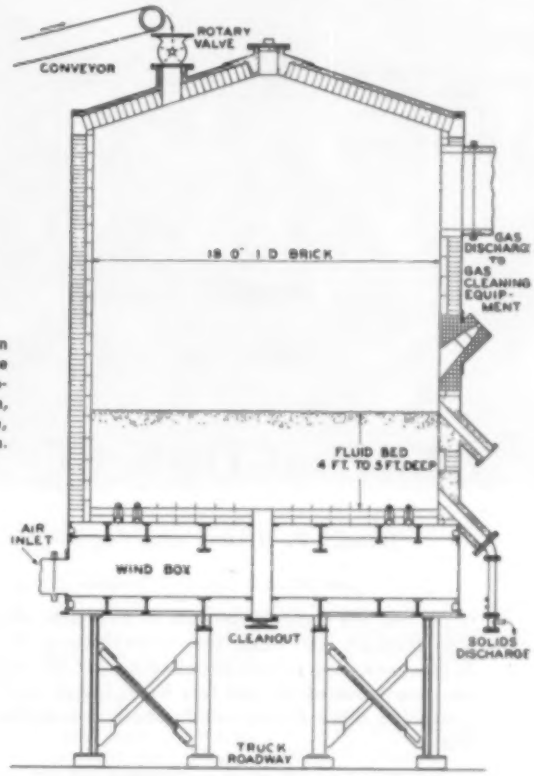


Fig. 2. Cross section of reactor. The DorrCo. Fluosolids system, Anaconda, Yerington, Nevada.

Table 2.—Screen Analyses of Crushed Leviathan Ore

Mesh	% cumulative plus Case 1	Case 2	Case 3
6	....	0.1	....
8	0.3	2.6	....
10	2.7	10.6	20.0
14	9.6	21.8	....
20	22.1	32.1	....
28	32.6	40.8	....
35	42.6	50.0	....
48	51.4	57.0	73.0
65	59.8	64.0	....
100	67.0	71.0	....
150	72.6	76.0	....
200	77.0	79.5	96.0
325	83.0	85.0	....
30 μ	86.8	88.2	....
20 μ	90.5	91.8	....
10 μ	96.0	96.7	....

Table 4.—Screen Analyses of Discharge Product from Fluid Bed

Mesh	% cumulative plus Case 1	Case 2
6	0.8	2.7
8	4.5	9.5
10	14.4	20.4
14	28.7	33.9
20	45.4	47.1
28	60.2	61.3
35	74.9	75.6
48	86.9	88.1
65	95.4	96.7
100	98.7	99.5

Table 3.—FluoSolids Operating Data, Product Distribution

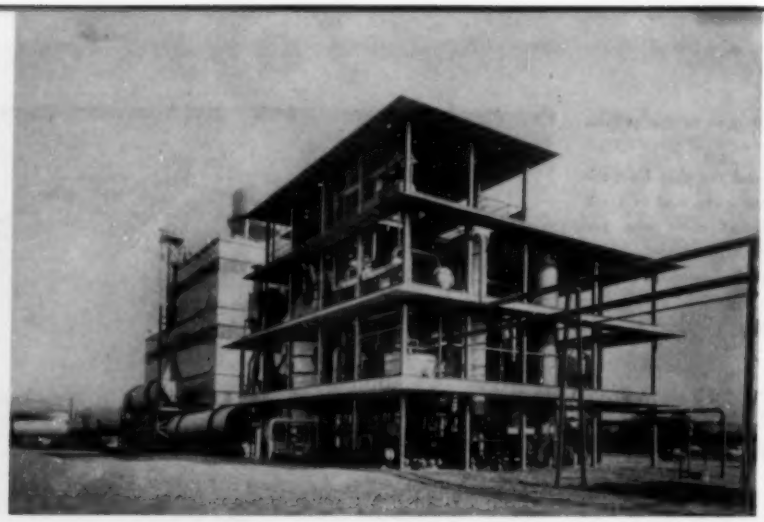
	Case 1		Case 2	
Feed rate, lb./min. wet	300		267	
Feed rate, lb./min. dry	279		248.3	
Calcine production, lb./min.	199		186.3	
Product distribution, lb./min.		%		%
Overflow	51.1	26.0	36.5	19.7
First compartment cooler	27.0	13.5	36.7	19.7
Second compartment cooler	18.9	9.5	21.5	11.5
First cyclone	76.0	38.0	72.0	38.5
Second cyclone	12.3	6.2	8.7	4.7
Third cyclone	5.7	2.8	2.9	1.6
Scrubber	8.0	4.0	8.0	4.3
Air flow, std. cu.ft./min.	8,000		7,000	
Space velocity, (dry gas) ft./sec.	1.7		1.5	
Space velocity, (wet gas) ft./sec.	2.1		1.75	
Carry-over, %	74.0		80.3	
Excess air, %	73.4		71.2	
Fluid bed temperature, °F.	1,275		1,300	

minerals processing

Operation of the FluoSolids system is controlled from a pressurized operating room in which are located four individual control panels—one for each reactor. These boards contain the variety of instruments, indicators, and recorders necessary to control the entire operation. Among these are a gas analyzer continuously indicating the sulfur dioxide content of the exhaust gas from the third stage of cyclones, a continuous temperature recorder listing temperature at four points in the fluid bed and in the two-compartment gas cooler and cyclones. Pressure drops between various points in the system are shown on a series of indicators and an air flow meter controls fluidizing air. Feed to the rod mills is also controlled from this panel.

For many years the lack of an economical method of recovering the contained sulfur has made known deposits of low-grade ore useless. The successful application of FluoSolids to the roasting of low-grade sulfur ores for sulfur dioxide production has opened up new resources of this vital element both in this country and abroad.

Presented at A.I.Ch.E. meeting, New York.



A typical soybean extraction plant of modern design.

Courtesy Blaw-Knox Company

EXTRACTION OF SOYBEANS | theory and mechanism

Donald F. Othmer and Jagdish C. Agarwal | Polytechnic Institute, Brooklyn, N. Y.

Neither the ordinary process of molecular diffusion through cell walls, the concentration of oil in the extracting solvent or miscella, nor the countercurrent use of solvent has been found by the authors to affect the extraction of oil from soybean flakes.

The retention of oil is unchanged by the concentration of miscella.

The rate of extraction is proportional to the 3.5 power of the oil remaining in the flakes at any time of the extraction (as the oil content drops to 1/10 of the initial value, the rate of extraction drops to less than 1/3,000). The rate decreases approximately as the flake thickness raised to the fourth power (thus increasing thickness by 3 times decreases rate by 80 times).

Extraction is a problem of fluid dynamics; and extraction rate is physically and mathematically defined by the Hagen-Pouiseulle law governing viscous fluid flow in capillaries.

Simple laboratory techniques have been developed which readily give the necessary data in a few hours for newly developed calculating techniques for designing plant extractors.

The mechanism of extraction which has been postulated and physically defined in these studies has made possible the correlation of the operation of a plant-type extractor with data predicted from laboratory determinations.

Of the 70 lb. of fats and oils used annually by each person in the United States, a large and constantly increasing source is soybeans, which give almost 20 lb. of soybean oil per person.

Oils from seeds, nuts, and beans are obtained either by expression, or increasingly by solvent extraction processes, which give higher recovery and better products. The design of extraction equipment has been largely empirical (*5*). This study was attempted: (a) to determine the basic theory and mechanism of extraction; (b) to find a short, simple, laboratory technique which would give the fundamental process data for plant design; (c) to develop graphical and other methods of estimating from these data the design, sizes, and specifications of industrial units.

As many factors were maintained constant in the experimental work as was possible without affecting the fundamental mechanism of extraction. Variation of other factors would probably affect the absolute values of the amount of extraction or rate, but not the mechanism. Thus:

(a) soybeans from only one shipment of average type were used and they were prepared identically for extraction in four different flake thicknesses.

(b) moisture content was kept constant at about 7%.

(c) only one solvent—commercial hexane—was used, but the amount of oil in the solvent was varied within the limits of commercial practice.

(d) a fixed temperature of 80° F. and atmospheric pressure were used.

(e) identical shaking action was obtained by an agitator especially designed to insure thorough contact without breaking the flakes. (It has been said that the degree of agitation and the velocity of the solvent past the flakes (2) have no appreciable effect on extraction rate.)

Extraction of Whole and Half Soybeans

A few score soybeans were carefully cut in half with a sharp razor blade to minimize crushing of cell walls. The cut surfaces were then washed lightly with hexane to remove only the oil present in the cells which were cut. These half beans and whole soybeans were extracted separately with hexane for 168 hr. Less than 0.08% of original oil in the whole beans and less than 0.19% of oil in the half beans was extracted.

This simple experiment indicates that even with a long contact time the solvent will not extract the oil from the mass of the bean by diffusion, either through the original peripheric surface or a freshly cut cross section. This confirms the conclusions of King and Katz (*4*), Karnofsky (*3*) who showed that it was impossible to apply Ficks law to solvent extraction of vegetable oils. Thus, diffusion is unimportant in oil extraction, contrary to its importance in other mass-transfer operations; and as long known industrially, the beans must be flaked or changed greatly otherwise if oil is to be extracted therefrom.

J. C. Agarwal is presently with Blaw-Knox Company, Pittsburgh, Pennsylvania.

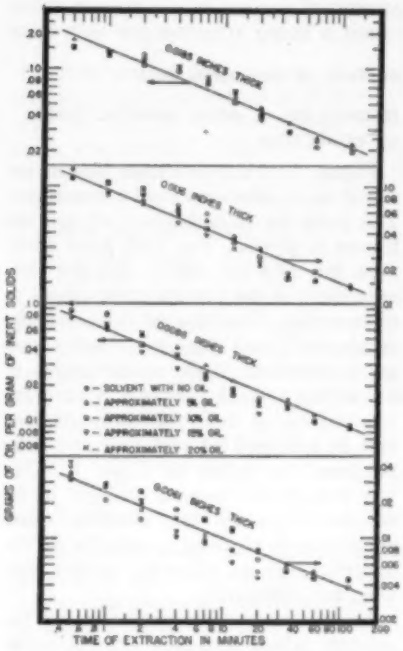
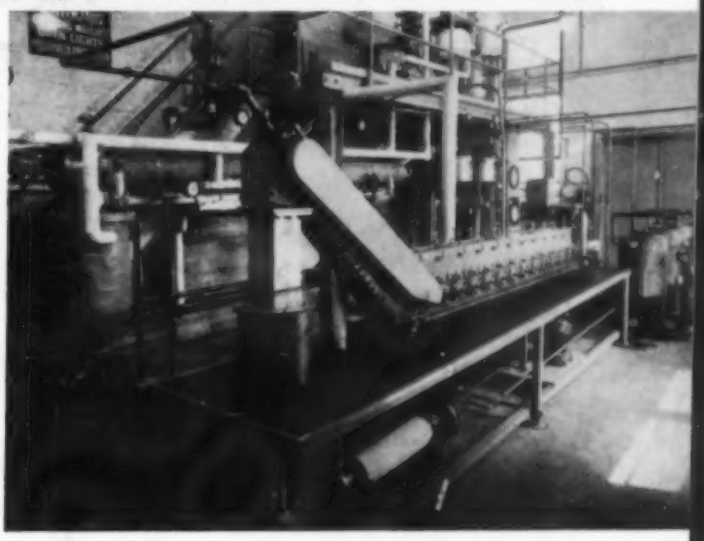

0.0185 INCHES THICK
0.0136 INCHES THICK
0.0096 INCHES THICK
0.0061 INCHES THICK
GRAMS OF OIL PER GRAM OF INERT SOLIDS
TIME OF EXTRACTION IN MINUTES

Fig. 1. Experimental extraction data: logarithmic plot of unextracted or residual oil (g. oil/g. inert solid) vs. time of extraction in minutes. Data for five different oil concentrations are plotted, and no consistent deviations are apparent from the lines, each of which represents one of the four different flake thicknesses.



Pilot plant extractor with fifteen stages.

Materials Used in Extraction Experiments

PREPARATION OF SOYBEANS

Soybeans (U. S. No. 2 Yellow) from a single shipment were all prepared by standard methods at one time. The beans were first cracked in a mill with rolls, 8 in. diam. × 18 in. long. The cracked beans were conditioned by water spraying to an optimum moisture content of approximately 12% and then flaked between rolls 10 in. diam. × 22 in. long, by the use of four different settings to obtain four different thicknesses. Flakes were then air dried to the natural equilibrium moisture content of approximately 7% and were stored in air-tight containers until used.

FLAKE THICKNESSES

Individual flakes numbering 100 were taken at random from each sample and the thickness of each was measured with a micrometer. As a frequency distribution diagram indicated normal statistical distribution of these readings, they were averaged to give thicknesses of 0.0185, 0.0136, 0.0096, and 0.0061 in.

processes

Table 1.—Average Experimental Values for Residual Oil After Extraction of Soybean Flakes

(Original oil content on dry basis 20.3%)

	Series No. 1 Flake thickness 0.0185 in. Moisture content. 6.9%		Series No. 2 F. th. 0.0136 in. M. c. 7.0%		Series No. 3 F. th. 0.0096 in. M. c. 7.43%		Series No. 4 F. th. 0.0061 M. c. 7.00%	
Contact time (min.)	Residual Oil[1]	Retention Ratio[2]	Residual Oil[1]	Retention Ratio[2]	Residual Oil[1]	Retention Ratio[2]	Residual Oil[1]	Retention Ratio[2]
½	.1559	0.796	.1284	0.827	.0901	0.867	.03724	1.191
1	.1359	0.769	.0992	0.849	.0709	0.906	.02634	1.201
2	.1190	0.794	.08216	0.795	.0472	0.914	.01933	1.197
4	.0981	0.784	.06019	0.854	.03548	0.963	.0142	1.145
7	.0775	0.796	.04718	0.822	.0250	0.936	.01173	1.158
12	.0591	0.755	.03404	0.800	.01873	0.888	.00895	1.237
20	.04197	0.748	.02449	0.869	.01398	0.931	.00630	1.215
35	.03055	0.742	.01728	0.764	.01319	0.843	.00549	1.131
60	.02388	0.802	.01557	0.869	.01025	0.863	.00477	1.190
120	.02107	0.792	.01408	0.831	.0088	0.936	.00418	1.138
	Over-all avg.	0.778	over-all avg.	0.828	over-all avg.	0.905	over-all avg.	1.180

[1] Residual oil content is expressed as g. oil/g. dry inert solids; values given are averages of those obtained for the five different oil concentrations in miscella.

[2] Retention ratio $= \frac{\text{g. miscella retained}}{\text{g. dry inert solids}}$. The values given are as averages of those obtained for five different oil concentrations in miscella.

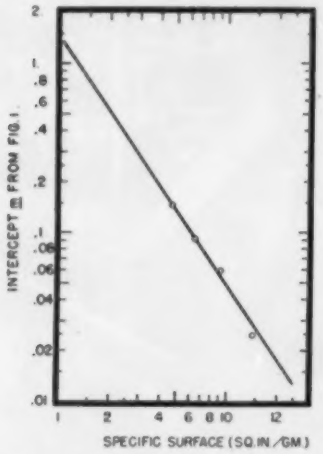


Fig. 2. Logarithmic plot of the intercepts, m, of lines of Figure 1 at time of 1 min. vs. specific surface, S, of flakes (sq.in. extracting surface/g. dry, inert solids). Slope = −1.468.

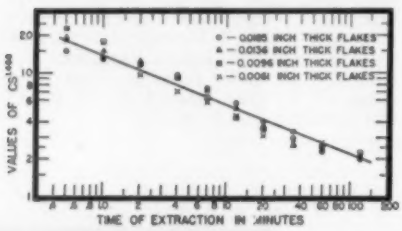


Fig. 3. Generalized representation of extraction data: logarithmic plot of residual oil, $CS^{1.468}$ vs. time to give a single line for all concentrations of miscella and all thicknesses of flakes, (specific surface to an exponent equal to the negative value of slope of line of Figure 2).

EXTRACTING MISCELLA OR SOLVENT

The solvent was commercial normal hexane with a boiling range of 135 to 145° F. (Skellysolve B from the Skelly Oil Company). To study the effect of different amounts of oil in the solvent (so-called miscella), synthetic miscellae were made of fixed oil concentrations. Fresh hexane and filtered soybean oil solutions from previous work were made up in five stock solutions of 0, 5, 10, 15 and 20% oil, in containers. These were absolutely vapor tight to prevent change of concentration by evaporation.

Experimental

Soybean flakes of four different thicknesses were extracted with the five stock miscellae of 0, 5, 10, 15, and 20% oil. This gave twenty series of runs, most series having runs at ten different extraction periods ranging from 30 sec. to 120 min. Thus almost 200 runs were made.

A run consisted of shaking a weighted mixture of flakes and extracting medium for the specified time in a vapor-tight Erlenmeyer flask. The specially designed shaking mechanism held ten flasks and gave each the same—340 reciprocating motions per minute. Blank runs showed that no solvent was lost by evaporation during the run.

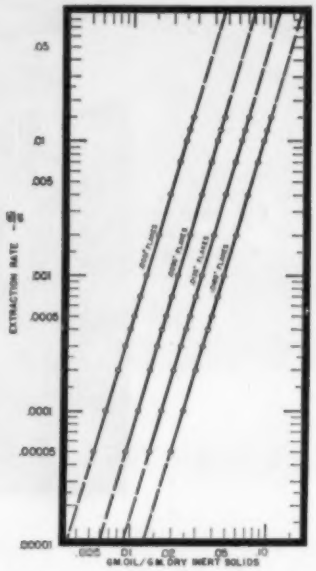


Fig. 4. Data of rate of extraction: logarithmic plot of the extraction rate (negative differential of residual oil with respect to time) vs. residual oil. Each different line represents a different flake thickness.

A survey of experimental methods of previous workers had been made; and a method of measuring the amount of extraction was developed, which was based on analyzing the oil content of the miscella after extractions. The residual oil, an important factor in subsequent studies, was defined as C, grams oil per gram dry, inert solids. This was calculated by a material balance of the known amount of oil in the solution before extraction and the amount of oil in the solution determined after extraction. Official analytical methods of the American Oil Chemists Society (*1*) were used.

The residual oil content after any given time, was found to be the same, within the limits of experimental errors, for each of the five different miscella concentrations. The average of these experimental values for residual oil after the same time were taken and are shown in Table 1.

A small deviation in the value of residual oil appears as a relatively large percentage error, especially when oil content is low. As the data were averaged, these errors tended to cancel each other. The slight scattering of the data is probably not significant for present studies of mechanism or for engineering purposes.

The amount of miscella retained per gram of dry, inert solids is called the retention ratio. It was found to be the same for each particular flake thickness, regardless of the oil concentration in the miscella. This is to be expected as the densities of different miscellae do not vary greatly, since oil and hexane have about the same densities. The larger amount of surface of the thinner flakes causes a larger retention per unit mass.

Analysis of Extraction Data

RESIDUAL OIL, C, AFTER DIFFERENT TIMES OF EXTRACTION

Figure 1 is a logarithmic plot of residual oil, C, after any time, t, in minutes. The point for each different oil concentration is plotted. For each flake thickness, the data fall near a straight line, regardless of the concentration of oil in the miscella. Thus the oil extracted, the residual oil, and the rate of extraction are independent of the concentration of oil in the solvent; and the values for residual oil at different concentrations may be averaged for each time and flake thickness, as shown in Table 1. This was unexpected because changes in oil concentrations in the miscella cause variations in physical properties of the miscella, such as viscosity, surface tension, and diffusivity.

Hence the specific properties of the solvent, which normally control diffusion and extraction rates, do not affect the present case; and molecular diffusion, since it would be dependent on these properties, which are seen to be unimportant, is therefore not a controlling factor. This conclusion has been noted above from the extraction of whole and half beans. Furthermore, since the concentration of oil in the solvent does not affect its action, there can be no advantage in countercurrent extraction.

EFFECT OF SPECIFIC SURFACE OF FLAKES AND GENERAL EXTRACTION RELATION

Soybeans are flaked in order to increase the amount of surface per unit mass, which has an important effect on any possible mechanism of extraction.

The actual specific volume of beans or flakes was determined as 0.087 cu.in. or 1.425 cc./g. dry inert solids; and with the exclusion of edges, values were calculated of the specific surface of flakes of each thickness expressed for convenience of measurements as square inches per gram of dry inert solids.

In Figure 1 the straight lines, one for each flake thickness, are parallel with a constant slope of −0.4. This indicates a general equation:

$$\log C = \log m - 0.4 \log t$$

$$\text{or } C = mt^{-0.4} \qquad (1)$$

In this equation

t is the time of extraction in minutes

C is the residual oil in grams of oil per gram of dry inert solids

m is a constant for each thickness or specific surface of the flakes, which may be evaluated from Figure 1 by taking the value of the intercept with the time ordinate for 1 min. (log 1 = 0).

A cross plot of these values of m vs. the corresponding values of S, the specific surface for the same flake thickness, also gives a straight line on logarithmic paper (Figure 2) which is represented by an equation:

$$\log m = \log 1.4 - 1.468 \log S$$

$$\text{or } m = 1.4S^{-1.468} \qquad (2)$$

Since the lines of Figure 1 are parallel, the right side of the equation shows the effect after any fixed time of extraction, of the flake thickness. Equation (2) and Equation (1) may be combined to give:

$$C = \frac{1.4}{S^{1.468}} t^{-0.4} \qquad (3a)$$

$$\text{or } CS^{1.468} = 1.4\ t^{-0.4} \qquad (3b)$$

For convenience, the several values relating to thickness are shown below.

The average values of residual oil, C, in Table 1 for different miscella concentrations at each flake thickness and time were multiplied by above values of $S^{1.468}$; and these products were plotted against time on logarithmic coordinates in Figure 3 to give a correlated plot of all extraction data taken. A similar logarithmic plot is obtained if the term $CS^{1.468}$ is plotted against the term $1.4\ t^{-0.4}$, i.e., the left vs. the right side of Equation (3b). This is the exact expression for all conditions. It is not so convenient in use since time appears to a fractional power; and it is easier to use the plot wherein time and residual oil appear to first power.

Equation (3) gives the general overall relation for extraction; i.e., the dependent variable, residual oil, as defined by the pertinent independent variables (a) flake thickness or specific surface and (b) time. Evaluation of the constants, i.e., the two exponents and one coefficient of Equation (3) from the plots of Equations (1) and (2) (as in Figures 1 and 2), gives a specific equation for each condition of temperature, type of solvent, moisture content, method of bean preparation, and all other variables which do not affect the fundamental mechanism of extraction.

RATE OF EXTRACTION

In designing industrial equipment, it is necessary to consider the extraction rate as well as the residual oil so that the throughput and size of the extractor may be evaluated. The extraction rate is the weight of oil per unit weight of inert solids removed per unit of time, $-dC/dt$. It is the negative of the rate of change of the residual oil content; and differentiating Equation (1) gives:

$$-dC/dt = 0.4\ mt^{-1.4} \qquad (4)$$

If the value of t in Equation (4) is substituted from Equation (1), the result is:

$$-dC/dt = 0.4m^{-2.5}C^{3.5}$$

$$\text{or } -dC/dt = 0.173\ S^{3.97}C^{3.5} \qquad (5)$$

Equation (5) is better for study than Equation (4) which is indeterminate at the start of extraction, i.e., zero time. For each flake thickness and value of m (or S), Equation (5) was evaluated for different values of C. These values of the rate were plotted on logarithmic paper in Figure 4 to give a family of four parallel, straight lines, each of which shows by the steep slope the tremendous decrease in the rate of extraction as the residual oil in the flakes lessens, i.e., as $C^{3.5}$. By comparing the individual lines, there is demonstrated the large influence of the thickness on the rate of extraction at any given amount of oil C in the flakes (i.e., rate varies as $S^{3.97}$ or as thickness to the -3.97 power. Thus, the thinnest flakes are approximately ⅓ as thick as the thickest flakes; and the ratio of the rates of extraction at any given value of oil in the flakes is seen to be almost exactly 80, which is $(⅓)^{-3.97}$ or $3^{3.97}$.

Conclusions from Experimental Data

Basic conclusions as to the mechanism of extraction may be drawn:

(1) The walls of the oil cells are, for all practical purposes, impervious to the oil and to the solvent and do not permit the diffusion of either. The almost total lack of extraction from whole and half soybeans indicates the absolute inability of either the solvent or the oil to diffuse through the cell walls and hence to the body of the solvent.

(2) The concentration of oil in the miscella has no effect on either total extraction or extraction rate. Hence, the extraction cannot be taking place according to Fick's law of molecular diffusion.

(3) The retention ratio is unchanged by miscella concentration. This is expressed as weight miscella per unit weight solids. For solvent differing in specific gravity from the oil, it might be expected that retention ratio on the basis of volume of miscella per unit weight of solids would be constant.

(4) The residual oil and the rate of extraction are exponential functions of the time of extraction, and give straight and parallel lines on logarithmic paper for different flake thicknesses.

(5) The rate of extraction decreases greatly as oil concentration in the seeds decreases, since it is proportional to the 3.5 power of the residual oil. Thus, as the oil content drops from an initial 20% to one-tenth that or 2%, the rate of extraction drops to less than 1/3000 of its initial value.

(6) The rate of extraction increases greatly with decrease of flake thickness (to nearly the −4th power). For the same oil concentration, decreasing the thickness to ⅓, in-

Pilot plant—soybean cracking and flaking rolls.

processes

Thickness of Flakes in.	S = Specific Surface of Flakes sq.in./g. dry inert solids	Intercept m Figure 1	$S^{1.468}$
0.0185	4.7	0.145	9.65
0.0136	6.4	0.092	15.1
0.0096	9.07	0.059	25.3
0.0061	14.25	0.0245	49.5

creases the rate 80 times. Thus, the largest possible specific surface is desirable, although if flakes are made too thin they break and make fines, which compact and do not separate easily from the miscella.

(7) All extraction data have been correlated to a single equation and single line on logarithmic paper; and the evaluation of constants allows the mathematical prediction of other conditions of extraction and of plant design.

(8) It can be inferred from Conclusion No. 2 that the extraction operation itself is not improved by countercurrent operation. The principal requirement appears to be a fairly intimate contact of solids and solvent for a specified time, after which the retained miscella should be removed by washing. Based on the observed experimental facts and conclusions therefrom, both the probable mechanism of extraction and the plant design can be developed.

oil cells may be a comb of honey which is immersed in water. The honey is contained in cells with wax walls which are impervious to the solvent for honey, i.e., water. However, if the walls of some of the cells have been broken previously by pressure on those at the surface, and by a combination of direct and hydraulic pressures on those in the interior, the honey from these cells with ruptured walls now can be dissolved or displaced by the ambient water. The honey in the ruptured cells at the surface will be dissolved or displaced first, and much sooner than the honey in those cells deeper within the comb, which must await the water searching through all the nearer, opened cells. This is believed to be substantially what happens in extraction of oil from oil-bearing flakes by a solvent which readily dissolves or displaces the oil first in the ruptured cells near the surface, and then progressively and much more slowly removes the oil from those farther and farther away from the surface.

Table 2.—Solutions of Soybean Oil in Commercial Hexane

% oil in solvent	density (g./cc.)	viscosity (centipoises)	surface tension dynes/cm.	surface tension × density/viscosity
0	0.662	0.35	18.0	34.1
10	0.687	0.40	19.7	33.9
20	0.712	0.46	21.5	33.0
30	0.738	0.60	23.3	28.1
40	0.760	1.00	24.6	18.65
50	0.785	1.80	26.5	11.40
60	0.808	3.20	28.0	7.00
70	0.833	5.50	29.4	4.44
80	0.858	10.20	30.8	2.60
90	0.883	21.00	32.5	1.38
100	0.907	50.00	34.0	0.617

ARCHITECTURE OF CELL STRUCTURE, MECHANICS OF SOLVENT PENETRATION

The inability to extract oil from whole and half soybeans clearly indicates that cell walls must be broken by a flaking operation, as has long been practiced, to allow the oil to be removed from the otherwise impervious cells. Nature makes the cell wall impervious to the oil; and it is also impervious to solvents (although it appears to be pervious to moisture.) After being crushed and flaked, the solids are a random and confused system of passageways through the many cells with broken walls. By this haphazard maze of capillaries, the solvent penetrates to the interior of the flake; and the dissolved or displaced oil is conducted to the surface and the bulk of the miscella. The extraction and its rate are controlled, therefore, by the capillary action of solvent penetration and solution exit.

An analogy to the architecture of the

Physical Study of Extraction

FLOW OF VISCOUS FLUIDS IN CAPILLARY SYSTEM

Since extraction and its rate are evidently controlled by the rate of penetration of a capillary system by the miscella, the laws controlling viscous or capillary flow should be considered. The Hagen-Poiseulle equation indicates that the rate of viscous flow through capillary passages, q, or volume per unit of time, is proportional to the pressure drop, ΔP, and inversely proportional to the viscosity of the liquid flowing, μ. Thus, for a given system:

$$q = (\pi \Sigma D^4/128 \Sigma L) \cdot (\Delta P/\mu) \qquad (6)$$

where ΣD is the sum of the diameters and ΣL is the sum of the lengths of the capillaries, and π has its normal value of 3.1416.

For any given solid system the quantity $(\pi \Sigma D^4/128 \Sigma L)$ is a constant, say, k; hence:

$$q = k(\Delta P/\mu) \qquad (7)$$

In an oil extraction system, ΔP, the driving force, equals the capillary back pressure. This, however, is directly proportional to the surface tension, γ, of the liquid. Therefore, if K is another constant,

$$q = K(\gamma/\mu) \qquad (8)$$

The weight of liquid flowing W equals volume q times density, ρ, or

$$W = K(\gamma\rho/\mu) \qquad (9)$$

ASSUMED MATHEMATICAL RELATION

It appears reasonable that the weight of liquid flowing should be directly proportional to its surface tension—since capillary attraction always is directly proportional to density and inversely proportional to viscosity.

The rate of extraction of oil is $-dC/dt$, g. oil extracted/(g. dry inert solids)/(unit time); and if this depends upon the rate of penetration or flow of the solvent or miscella into the flakes, then if a new value is assumed for K:

$$-(dC/dt) = K(\gamma\rho/\mu) \qquad (10)$$

Thus at a given value of C the rate of extraction of the oil is proportional to the surface tension and density of the extracting liquid and inversely proportional to its viscosity, or for other values of the residual oil concentration in the flakes:

$$-(dC/dt) = K(\gamma\rho/\mu)f(C) \qquad (11)$$

where $f(C)$ is some function of the residual oil concentration.

The values of surface tension, γ, of density, ρ, and viscosity μ of the extracting medium as well as of the ratio $(\gamma\rho/\mu)$, i.e., surface tension times density divided by viscosity, have been evaluated for 0-100% oil concentration in hexane and are shown on Figure 5. The viscosities and densities of solutions of soybean oil in hexane have been reported (*6*) and the surface tension was determined by the capillary rise method (Table 2).

The function $(\gamma\rho/\mu)$ remains practically constant up to a miscella concentration of 25% oil. This is a higher concentration than encountered either in this study or in usual practice. Therefore, Equation (11) reduces to:

$$-(dC/dt) = kf(C) \qquad (12)$$

where k is another constant. The relationship derived empirically from the experimental data for any fixed flake thickness was also a function of the residual oil, C, alone.

Application of Methods Developed to Extractor Design

To design an extraction system using a given solvent for a particular oil-bearing material of a fixed size or thickness with a given solvent, the following steps appear necessary from the experimental work described in this paper.

(a) Laboratory extractions are made to determine residual oil remaining at two different times to define the curve, although more points will eliminate the possibility of casual errors.

(b) The residual oil, C, is plotted on logarithmic paper against the time of extraction, t, as in Figure 1. The straight line obtained has the equation $C = mt^b$ (where b and m are constants depending on conditions).

(c) The contact time necessary to obtain the desired final low residual oil, C, may be determined by inspection from this line.

(d) The extractor volume is calculated as the sum of the volume of all sections equal to that required to give the necessary holdup or extracting time for the specified amount of solids to be in contact with the amount of solvent required to extract the oil, and give the desired final miscella concentration which is fixed by the process economics, retention ratio, and the maximum concentration of oil in the final miscella at which the $\gamma\rho/\mu$ ratio is not significantly different from that for pure solvent. Adequate washing of miscella from extracted solids is provided separately.

If the most desirable specific surface (or flake thickness) is not known from, or controlled by, other considerations, it may be desirable to determine the extraction functions for all possible specific surfaces. In this case:

(a) The laboratory extractions are repeated for solids of at least one other specific surface (flake thickness) to determine the residual oil at one time (or more if convenient).

(b) A second straight line is drawn on logarithmic paper through the point or points parallel to the one of the first flake thickness. A third and fourth also may be drawn to define $C = mt^b$ at other flake thicknesses.

(c) Values of m, the intercept, are taken at times of one minute and are plotted vs. the specific surface on logarithmic paper (as in Figure 2).

(d) A master plot of extraction data for all desired values of specific surfaces can be made, as in Figure 3, or by plotting the left side vs. the right side of Equation (3b). The time required for extraction down to any specified residual oil content may readily be seen from the plot of (c) or from this for any chosen degree of comminution or flake thickness.

(e) Extraction rates for any flake thickness at any given value of residual oil may be determined from Equations (4) and (5), as explained previously.

(f) After the desired specific surface (flake thickness) has been chosen, the necessary time for any given, final low residual oil desired and the size of equipment are determined by inspection of graphs.

The greater rate of extraction for greater specific surface (or lesser flake thickness) — and the correspondingly lower time of holdup and smaller units— may be balanced against the disadvantages of a practical nature in increasing the specific surface. One aid may be a plot of a series of lines such as Figure 4, and a cross plot of the intersections at one value of residual oil. This will indicate graphically the large effect (smaller equipment size) for larger specific surfaces and will be useful in the determination of paragraph (e).

Since the concentration of oil in the solvent has been shown to have no effect, it follows that the usually specified countercurrent extraction is not necessary; and only one extraction stage would be required in a commercial unit as was used in the laboratory tests. A simple agitated holdup of the solvent and solids will suffice for the extraction, though it will be desirable to provide adequate washing of the miscella off the meal after the extraction itself. The washing can be as rapid as feasible in standard mechanical equipment by successive washing with fresh solvent or by countercurrent washing. This washing may be by use of solvent in sprays or solvent in bulk. The amount of washing or the number of washing steps required can readily be calculated by material balances in which the retention of miscella by the solids is assumed to be constant.

Pilot Plant Run

To determine the correlation between the mechanism and equations coming from analysis of the laboratory data with industrial operations, a Kennedy Extractor (5) was used. The soybeans, although of the same type as used in experiments—just referred to, were of a different shipment and thus varied slightly. They were cracked and flaked. The effective thickness was determined as 0.012 in. by averaging micrometer measurements of 100 flakes. The oil content was 21.0% on dry basis (0.2675 g. oil/g. dry inert solids) and the moisture content was 10.6%.

Flaked soybeans were fed uniformly to the head end of the 15-section extractor by a screw conveyor. Extracted flakes were removed from the last section by a drag conveyor and dropped into a screen-bottomed receiver. Commercial hexane (Skellysolve B) was sprayed onto the extracted flakes leaving the extractor on the drag conveyor. It then flowed countercurrently to the flakes and discharged at the head end, with the extracted oil, to a surge tank from which it was pumped through a filter to a weigh tank.

Fresh flakes, fresh solvent, and discharge miscella were weighed hourly. After 11 hr., steady-state conditions were reached within the limits of controls possible. Data taken in two additional hours were used for calculations. Samples of the miscella were taken from alternate sections.

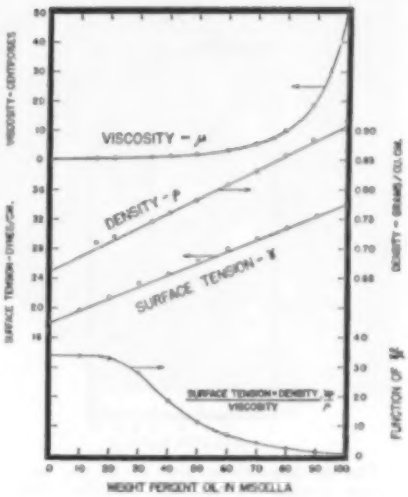


Fig. 5. Physical properties of different solutions of soybean oil in commercial hexane (i.e., miscella). Plots of viscosity (centipoises), density (g./cc.), surface tension (dynes/cm.) and of surface tension × density/viscosity all vs. wt. % oil in miscella.

The residual oil in the flakes in each section and in the discharged flakes was determined by material balances. In making these material balances it was assumed that, since the voids or cellular volume of the flakes and the surface entrainment are constant throughout, the amount of liquid retained in the solids stream from any section is also constant. Thus, the sum of the amount of miscella retained by the solids stream from any section, plus the unextracted oil in the solids, is constant. As the oil content of the incoming and outgoing miscella as well as incoming solids stream in any section is known, the oil content of the outgoing solids stream can be calculated. This amount of oil in the outgoing solids stream is contributed by unextracted oil plus the oil in retained miscella which is known. Therefore, the unentrained oil or the residual oil in the solids can be evaluated.

The time of holdup or extraction in each section was determined by dividing its volume by the volume of throughput per minute. This was 3 min., i.e., total time of extraction for fifteen sections was 45 min. The pertinent data are presented in Table 3, Figure 6, and Figure 7. Results were compared with those predicted by the general equation for residual oil as function of time from laboratory runs in flasks: $C = mt^{-0.4}$.

Values of C were calculated by reading the values of m of 0.077 from Figure 2 for the specific surface of 7.25 sq.in. corresponding to 0.012-in. flake thickness, and substituting values for

What kind of training should our

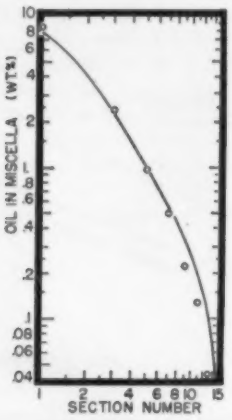


Fig. 6. Logarithmic plot of oil vs. section number in Kennedy Extractor. The points were determined values in the pilot plant run. The smooth curve is of calculated values.

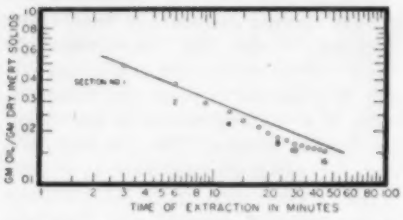


Fig. 7. Comparison of predicted values of extraction with those obtained in Kennedy Extractor. Logarithmic plot of residual oil vs. time of extraction. The line comes from Figure 1 and 2 for a thickness of flakes of 0.012 in.; the points are numbered as to sections of extractor, and each represents an additional 3 min. of extraction time.

the time t. These predicted results give the straight line on the logarithmic plot shown on Figure 7. The experimental points for each section (always an additional 3-min. extraction time) are also shown on Figure 7. This indicates as good an agreement between the predicted and the observed values of residual oil after extraction as could be expected from the unavoidable variations in controlling the important values of the several streams during the test period. Furthermore, the moisture content of the beans used was 10.6% as compared to about 7.0% for the beans used in the laboratory; and there may have been other slight variations in the beans or their preparation. The points for the sections of the plant extractor indicate that a slightly greater slope may be more representative of the pilot plant line for extraction as compared to the line for the laboratory runs. The possible variations of the beans, moisture content, or preprocessing seem to be more important than the difference in mechanics of the laboratory and plant extraction. It would have been preferable (and would be done in practice) to run two or three tests in the laboratory on the exact flakes which were to be run in the plant in order to obtain the single line with whatever slope for both the laboratory and the plant extraction. Nevertheless, the plant design which would have been achieved by the use of the laboratory data would be close indeed to its actual performance.

The points of Figure 6 give a logarithmic plot of the concentration of oil found in the miscella vs. the section number. Comparable values have been calculated from over-all material balances for this extraction and are listed in the last column of Table 3. When plotted, they give the smooth curve of Figure 6 which is asymptotic to an abscissa having the value of the initial concentrated discharge (somewhat more than 15%) since this would be at the zero stage. The curve is also asymptotic to the ordinate stage 15 since it approaches there a value of zero. The deviations from this curve are small in absolute values of oil and well within the experimental errors for the analytical determinations for small amounts of oil.

The close agreement of the experimentally determined values of the concentration of the miscella with those predicted by these methods and plotted as the smooth curve adds confidence to the techniques developed.

Table 3.—Operation of 15-stage Kennedy Extractor

Soybean Flakes, 0.012 in. Thick Containing 10.6% Moisture and 0.2675 g. Oil/g. Dry Inert Solids

Feed: 6.375 lb. soybean/hr.
10.844 lb. solvent/hr.
Discharge: 7.313 lb. miscella/hr.

Extractor section, no.	total extraction time, min. (discharged solids)	residual oil, C, g. oil/g. dry inert solids (leaving section)	experimental % oil in miscella (entering section)	calculated % oil in miscella (entering section)
Bean feed				
Miscella discharge	0	0.2675	15.90	15.35
1	3	0.0489	8.46	7.73
2	6	0.0377	.....	4.03
3	9	0.0291	2.41	2.24
4	12	0.0261	.....	1.435
5	15	0.02305	0.967	0.987
6	18	0.02110	.....	0.727
7	21	0.01938	0.498	0.557
8	24	0.01833	.....	0.437
9	27	0.01760	0.224	0.346
10	30	0.01670	.....	0.259
11	33	0.01630	0.127	0.202
12	36	0.01595	.....	0.1525
13	39	0.01570	0.043	0.104
14	42	0.01550	.....	0.0647
15	45	0.01510	.....	.....
Bean discharge—Miscella feed	..	.....	0.000	0.000

Acknowledgment

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Presented at A.I.Ch.E. meeting, St. Louis, Missouri.

What kind of training should our universities be giving the chemical engineers of tomorrow? In this thought-provoking paper, Professor White looks beyond the customary boundaries and proposes a bold, new approach. That these ideas are practical as well as revolutionary, is evidenced by their incorporation—beginning this fall—in a curriculum at the University of Michigan . . . *—Editor.*

chemical engineering AND science engineering

Robert R. White | University of Michigan, Ann Arbor

Chemical engineering as it exists today and as it may exist tomorrow—with the problem of educating young men to take their places in the professional world of the future—is a large and important area to survey. This is an introspective operation, which usually ends in a resounding declaration to the effect that we stand four square behind chemical engineering fundamentals.

"Ours," Dean ten Hoor has said, "seems to be an era of undiscriminating allegiance to good causes and a striking symptom is to be found in the recent popularity of educational surveys. I have lived through eleven without noticeable improvement in myself or my neighbors. The surveyors are always from another state or institution . . . brought in because of their objectivity; [this] being the capacity for discovering faults abroad which you cannot recognize at home. To be a good educational surveyor . . . you must have a sharp eye for foreign motes but a dull one for domestic beams. You must be a contented extrovert, so that after diagnosing the faults of others, you can continue to live in perfect comfort with your own" (*1*).

Pressures Make the Problem

Stating the problem of chemical engineering education turns out to be a problem in itself. To do so, it is best to begin with the changes that have taken place in the industrial environment in which many chemical engineers have careers. The scientific advances of the past fifteen years have brought a technological and social revolution in the United States and as a matter of fact in the rest of the world. The catalytic processing of petroleum, the separation of uranium isotopes by diffusion, nuclear reactors, a multibillion plastic industry, jet aircraft propulsion, new developments in communication and control devices–these are only some of the discoveries and developments. This new industrial revolution has confronted the engineer not only with technical problems involving what used to be called electrical, mechanical, and chemical engineering but also with numerous difficulties involving the psychology and behavior of the human beings who must work with these new machines and devices.

New products, new processing techniques, new industries, an unprecedented scale of manufacture, of research and development by industry and by government–these have created new concepts of the functions of technical manpower in industry and in society. They present unprecedented opportunities to educated technical people but at the same time they have established new demands on the education of technical men.

Today when industry describes its needs to universities, it demands a knowledge of numerous specific fields, such as instrumentation, statistics, kinetics, thermodynamics—the list is endless—but with the demand a new note is struck. Industrialists say not only, "give us men who can write reports and who can speak," but also they add, "give us men who are emotionally mature, with a broad viewpoint, able to think in terms of interacting systems involving money, science, and people."

What Has Happened

One result of these pressures has been a broadening of the scope of engineering and particularly the disappearance of the classical boundaries of the various professional divisions of engineering. In other words, today we cannot define the profession of chemical engineering except by saying, "It is what chemical engineers do." Another confusing result has been an apparent inversion in the quantity and often the quality of basic research produced by industry and by institutions of higher learning. Whereas only twenty years ago university research along fundamental lines occupied a preeminent position with respect to quality and quantity, today the scope and depth of fundamental work in industry and government exceed that of universities in many fields and in different ways.

The efforts of universities to educate engineers for modern industry have resulted in straining existing curricula. One obvious symptom of this strain has been the virtual disappearance of elective work in conventional programs. There is simply no room to add anything more to take care of demands for specific subject matter that pour in from all sides. Another symptom is the splintering of the professional divisions of engineering as reflected both in curricula and in the number of different professional societies. Where once there was only one kind of engineer (what we now would call a civil engineer), today there are literally dozens of categories and subcategories.

The splinter process in chemical engineering is apparent but not often mentioned because of our reverence for past accomplishments. Whereas, at one time, chemical engineering could be characterized among the profession by a relatively few Unit Operations, today there are so many Unit Operations and Unit

Processes, largely redundant, that we can no longer communicate effectively with one another in these terms.

Our world is undergoing such rapid change at the present time that we cannot extrapolate our knowledge of specific engineering skills sufficiently far to the future to render the results of much use either to the student or his educators. However, although it is impossible to predict the future boundaries of engineering, it is certain that the future engineers must also be scientists with a broad and liberal base of understanding if they are to have the versatility and intellectual virility to meet the needs of our technical world. These needs require intellectual power in the application of science rather than the specific know-how of today's industrial procedures which become obsolete almost by the time the student graduates.

Engineering arose from the need for men who were familiar with industrial arts. It thrived because universities teaching engineering added scientific knowledge and placed engineering graduates in a position of intellectual leadership from which great advances in industrial techniques were made. However, whereas it was once possible to teach industrial arts effectively and reasonably completely, this is now an almost hopeless task. Yet much of the present-day engineering curricula are based on the premise of teaching a considerable quantity of such know-how.

It's Time to Broaden

It is interesting to note that the companies most active in research are least specific in their demands on curricula and focus their attention on the broad educational values rather than on specific training. It is high time that this be done in engineering education. Although our present curricula show great strides in adaptation to a broader viewpoint, the changes necessary are so radical that they argue for a new beginning rather than for the successful prosecution of many revolutions or placing additional strain on existing programs.

We must also look at the men. By and large, the intelligence of the homo sapiens has changed but little through the years and the I.Q. of our high school graduates constitutes a definite boundary to our efforts. Our world is increasing in complexity and, therefore, demands more social skill from its inhabitants. Like it or not, the increasing emphasis on so-called social sciences in our high schools is a reaction to a need and is probably here to stay. We are burying our heads in the sand if we are not adaptable to these as well as to our technological needs, even though we deplore the decrease in emphasis on the sciences of mathematics, physics, and chemistry.

To further complicate things, our society by its trial-and-error processes, informs us that a young man should prepare himself to earn a living and establish a home sometime in his early twenties and this fixes a four-year, or possibly slightly longer, period for college work by those of our young people who can arrange college at all. Although this can change over a period of time, we must accept this also as a realistic boundary condition unless we propose to turn our backs on the problem by selecting only the exceedingly bright pupils or by lengthening the college program. One need not quote the statistics on the supply and demand for engineers to show the fallacy of such a policy.

Our basic problem, then, is to educate an average man over a period of four years or slightly longer for his effective participation in a complex technical world for a future that cannot be described except in the vaguest of terms. It is apparent then that we can solve this problem only through an improvement in the efficiency of education.

Our Chances for Improving Efficiency Seem to be Along the Following Lines

1. Changes in environment dictate that we preserve a maximum of flexibility in our engineers and, therefore, in their training programs. We must subscribe to the principle "What are the minimum specific requirements with which we shall permit graduates to escape with a bachelor's degree?" We shall find that even such minimum requirements crowd the curriculum.

2. Far more important than know-how, even in the sacred area of unit operations, is an intimate familiarity with the operational viewpoint of science—the meaning of a fact and the different meanings of facts in different areas of knowledge. This can be obtained only by laboratory and theoretical experiences over a broad area. It cannot be obtained by constrained programs of specialization.

3. Since we are educating engineers, people who must be more than scientists, we must preserve the engineering viewpoint through a large part of the learning process. The engineering viewpoint may be summarized as a willingness to do the best we can scientifically and intuitively with our problems, always completing the process with some kind of an answer.

4. In everything we teach, we must emphasize the development of intellectual power above everything else. If we can achieve this, it matters little what specific subject matter we cover. We miss the point when we organize our courses only around the coverage of subject matter.

It is interesting to observe that we in engineering and in chemical engineering are not alone in these problems. The doctors, lawyers, and even those in literature and the arts, are laboring under similar difficulties.

"At a conference in New York, sponsored by the Fund for the Advancement of Education, the topic for discussion was the whole field of professional education, but the medical, legal and engineering members kept the discussion concentrated almost entirely on the problems of professional preparation. . . . On the one hand, the advance in knowledge and the increase in complexity of the field have made inadequate the span of years traditionally assigned to education for the profession. As a natural result there is a strong desire to push more into the years of preparation. On the other hand, the mounting cry both within and without the professions is that professional men should be not only competent in their fields but also good citizens and well-educated men. This goal demands less emphasis on direct preparation for the particular profession" (*2*).

What We Are Doing at Michigan

During the fall of this year we are initiating at the University of Michigan a program leading to the degree of B.S.E. (Science), the object of which is to support the ideas discussed here. Above all it is designed to develop the creativeness and analytical power of its students. It not only provides a sound education on which a student may base a technical career, but also constitutes an ideal preparation for graduate work in either engineering or the sciences.

Specifically the program provides a powerful integration of mathematics, physics, chemistry, and other science in a curriculum characterized by unusual flexibility in the elections of professional engineering courses. A student can transfer without penalty to the other professional programs at the end of two years or he can create his own professional program by suitable elections of related professional courses. A highly integrated sequence of newly developed courses in mathematics and science during the first two years complements new courses in engineering science which form the basis of most engineering curricula, such as statics, dynamics, fluid mechanics, electricity, magnetism, electronics, and thermodynamics. All the science courses and many of the engineering science courses involve laboratory work. During the last two years, the student has great flexibility in electing courses in science, engineering, and other areas to suit his particular interests and to broaden his understanding of the human society in which he must work.

FLEXIBILITY OF COURSES, STUDENTS OPTION

The program may be considered as being made up of four-course categories:

1. Courses in English, drawing, mathematics, chemistry, and physics designed

to achieve the basic level of attainment required of all engineering students in all fields.

2. Advanced mathematics and engineering science to gain a broad understanding of the science and engineering sciences which apply in all engineering programs. The effect of this work is to give the student a scientific background equivalent to what is now the normal level of scientific attainment required for the M.S.E. degrees.
3. A professional group option. Although the students can elect sequences of courses now used in the conventional programs, he will be encouraged to formulate his own sequence of courses. The emphasis will be placed on the integration of the professional group which is not necessarily limited entirely to technical material.
4. Non-technical courses.

The number of new courses involved and the strong emphasis on science make the Science Engineering program somewhat experimental in character. A strong integration between the courses in mathematics, science, and engineering science is a primary objective. Therefore, it is imperative that the evaluation of the program and the progress of the students be carefully followed on a week-to-week basis.

It is contemplated that all those actively connected with the teaching and administration of the program will have regular and frequent meetings, either once a week or once every two weeks to review their common problems. All homework, problems, quizzes, bluebooks, etc., from all of the courses will be circulated among the entire group.

DIFFERENCES BETWEEN SCIENCE ENGINEERING AND CHEMICAL ENGINEERING PROGRAMS

The Science Engineering program is shown in Figure 1. The dotted lines show elections which might be made by a Science Engineering student who wished to direct his technological effort towards chemical engineering.

One difference between the science engineering program and the usual chemical engineering program is the omission of general chemistry, qualitative and quantitative analysis in the science engineering program, and the addition of physical chemistry beginning in the freshman year. One major objective of the science courses is to develop the periodic table on the basis of atomic structure and to rationalize the properties of matter in these terms. Another difference is the addition of work in the physics of solids and modern physics in the last two science courses shown in Figure 1.

The detailed teaching of applications of science in engineering is accomplished in the Engineering Science courses of statics, strength of materials, dynamics, fluid dynamics, electricity and magnetism, circuits, electronics, thermodynamics, rate processes and engineering materials. Another major change is the teaching of calculus in the freshman year. The Science Engineering student progresses through elementary differential equations and may then elect further mathematics in the regular university offerings or one of a number of new courses now being planned in the Engineering College.

The course on engineering materials will organize the properties of materials on the basis of solid state physics and thermodynamics.

The course on rate processes will deal with the engineering applications of heat, mass and momentum transfer, and chemical reaction kinetics.

The professional elections, shown in Figure 1, incorporate courses in equilibrium stage operations (labelled Unit Operations), metals, process and equipment design, laboratory, and organic and physical chemistry.

Over and above the requisites specified, the eleven hours' requirement of work in nontechnical areas remains. The resulting curriculum is at least as strong in chemical engineering as the conventional chemical engineering curriculum, and provides more science and mathematics and more humanities. In addition, it has the virtue of being a common program with many students not focused towards chemical engineering.

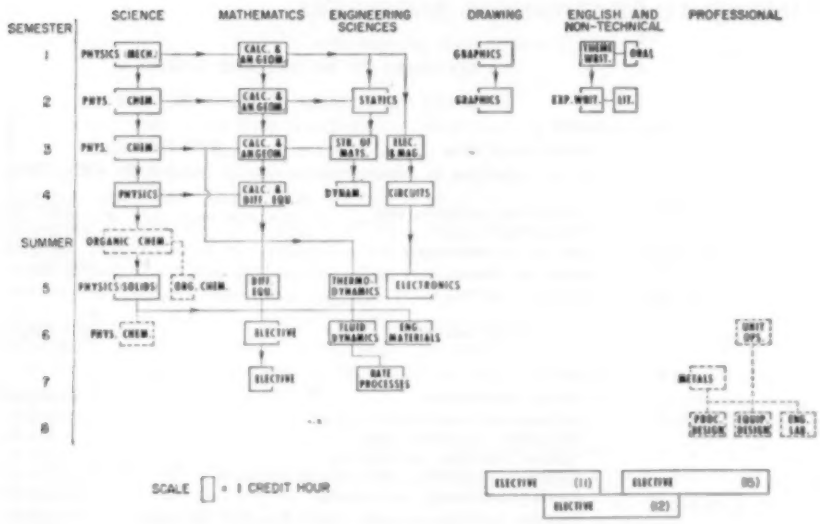


Fig. 1. Chart showing science engineering program at University of Michigan.

What We Believe to Be the Advantage

It is important to note that this program avoids the present defect of many undergraduate programs for those contemplating graduate work which in effect attempts the job of teaching professional know-how and fundamentals twice, once to undergraduates and again in the graduate programs.

A closing word should be said about chemical engineering in general. We believe the present organization of Unit Operations, Unit Processes, and Reaction Kinetics should be abandoned and that a classification based upon equilibrium stages (really an application of first and second law thermodynamics) and rate processes should be adopted. The latter approach has proved to be successful on both the graduate and undergraduate levels during the past two years at the University of Michigan, particularly in the coordination of the application of chemical reaction kinetics with heat and mass transfer. These subjects employ the same basis for definition, process design, experimental measurement, and philosophy of correlation. Teaching them in unified courses results in vastly improved effectiveness in covering subject matter, but more important in developing the ability of students to handle new and complex problems.

careers

Literature Cited

1. ten Hoor, Marten, "Education for Privacy," *The American Scholar*, **23**, page 28 (1953-54).
2. Teele, S. F., Conference on Higher Education in Michigan (November 17-18, 1955).

Presented at A.I.Ch.E. meeting, Houston, Texas.

Photo courtesy of Los Alamos Scientific Laboratory, University of California.

AUDITOR'S REPORT

We have examined the balance sheet of the American Institute of Chemical Engineers as of December 31, 1954 and the related statement of income and surplus for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the accompanying balance sheet and statement of income and surplus present fairly the financial position of the American Institute of Chemical Engineers at December 31, 1954, and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year except for the change in accounting for fixed assets and depreciation as referred to in the financial statements.

F. W. LAFRENTZ & CO.
Certified Public Accountants

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

BALANCE SHEET

DECEMBER 31, 1954

Assets		
Current assets:		
Cash on hand and demand deposits	$13,247.96	
Cash in savings institutions	109,785.10	$123,033.06
Investments, at cost including accrued interest		70,231.22
Accounts receivable, net		27,686.58
Inventory, at cost		15,551.06
Total current assets		$236,501.92
Deposits at airlines and post office		1,143.07
Total		$237,644.99
Trust and special funds:		
Cash on deposit	$72,896.48	
Investments, at cost	3,000.00	$ 75,896.48
Total		$313,541.47
Liabilities		
Current liabilities:		
Accounts payable		$ 16,442.40
Total current liabilities		$ 16,442.40
Deferred income		51,200.71
Institute funds		5,600.39
Surplus		164,401.49
Total		$237,644.99
Trust and special funds:		
Research Committee fund	$72,896.48	
Albert E. Marshall fund	3,000.00	$ 75,896.48
Total		$313,541.47

STATEMENT OF INCOME AND SURPLUS

FOR THE YEAR ENDED DECEMBER 31, 1954

Income:		
Membership dues	$200,504.32	
less allocation to subscriptions	62,532.00	$137,972.32
Membership entrance fees		14,077.00
Publication income		350,356.27
Income on investments		4,952.79
Meetings income		1,500.31
Sundry income		327.45
Total income		$509,186.14
Expenses:		
Publication expenses		$183,396.05
Salaries and commissions		220,212.26
Employees' retirement plan		6,039.16
Federal insurance contributions		2,666.42
Membership directory and meetings programs		29,833.38
Printing, stationery, and supplies		19,009.03
Postage, auditing, insurance, telephone, and telegraph		21,899.80
Rent and electric		18,001.55
Travel		8,767.36
Participation in professional groups		4,088.68
Committee expenses		3,049.10
Awards		1,523.52
Miscellaneous		6,772.21
Total expenses		$525,258.52
Operating loss for year		$ 16,072.38
Add:		
Moving expenses		3,235.31
Charge off of furniture and fixtures:		
Cost less reserve for depreciation as of January 1, 1954	$12,089.99	
Cost of purchases and renovations in 1954	39,600.08	51,690.07
Net loss for year		$ 70,997.76
Surplus, January 1, 1954, after restoring net reserve for publication program at December 31, 1953 ($42,182.70)		235,399.25
Surplus, December 31, 1954		$164,401.49

The net balance of furniture and fixtures at January 1, 1954, and additions during 1954 were charged to operations in accordance with resolution of Council passed at meeting of November 12, 1954. If there had been no change in policy, the amount charged to operations in 1954 would have been $11,740.56 instead of $51,690.07 as shown in the statement, a difference of $39,949.51.

eral manager, Petroleum Chemicals, dent, I. F. Pritchard, how the efficiency

Members of the Institute and guests will get together with leaders of chemical engineering management at A.I.Ch.E.'s September meeting for briefing and discussion of . . .

Broad social duties and accomplishments, how to get into management
Profit potential in Atomic Energy
Growth of our industries by integration
Revolutionary power for the chemical industry
Where we are going and how

MANAGEMENT — at Lake Placid

W. J. Farrisee, Jr.
Behr-Manning Division, Norton Co.

D. J. Lynds
Associate Editor

If you can take some time away from the woods, the lakes, the mountains, and all the other good things about Lake Placid's luxurious Lake Placid Club, you'll get a thorough briefing on what process management is thinking, and you'll get it from the inside, the men who know because they *are* management. Do you want to know what's happening in the industry, why, and where it's going? Then come on up to Lake Placid, September 25 to 28.

Top management will be there in force, there'll never be a better chance to get the management picture in the chemical process industries, get it straight and get it all, in four days (or more, if you really attach yourself to Lake Placid) of informal talking with engineering leaders. In the meeting hall, cocktail lounges, on the links, or just sitting out under the trees, they'll be there to tell what management is doing and thinking, what is going to happen next and why, where the engineer fits in management, what is wanted from him, and where the process industries are going from here.

Management is always looking ahead, and there'll be plenty of time to find out what they are looking at, where the next big steps will come. Chemical engineers are very much under the eyes of management these days as one of the best possible sources of new management material, but not all are ready for the job. Come up to Lake Placid and you'll find out why, what engineers should do to equip themselves for management positions, where to look for big future opportunities.

Engineers In Management

Striking at the heart of the question of engineers in management, R. K. Gottshall, president, Atlas Powder, will tell the engineers what management thinks of them as potential management material, what top posts call for when you get there, how best to get there. It is clear that engineers are in or entering management all the way up to the top—one-third of men now in management have had considerable engineering training or experience. Gottshall himself is a chemical engineer and in his opinion there isn't much a modern company can do without involving the engineer—that is reason enough for having engineers at the top.

As part of the symposium on the social competence of the engineer, led by James Donovan, president, Artisan Metal Products, Gottshall will show which is the best of the many paths engineers could follow to top management. Does management want the specialist or the broadly trained man with rounded experience? The key job of a manager is dealing with people. How does this affect the engineer and his choice of job experience? What about the engineer's tendency to think a problem through thoroughly, will it help him as a manager, or will it hamper the necessity to make quick decisions, often without full data at hand?

What H. F. Smiddy, vice president and manager, Management Consultation Services, General Electric, will try to tell is what makes a successful manager. Is there a pattern which can be deduced into a science, can this science be taught. GE has done much work on this problem, come up with vital answers, and Smiddy will discuss those answers in detail at the meeting banquet.

Maybe you've never thought of yourself as an international diplomat—but as a chemical engineer you would be well qualified. How? Well that's a good story, and H. W. Page, director, Standard Oil (N.J.), will tell it(with inside stuff on recent international negotiations conducted or aided by chemical engineers), has the startling facts to prove his point.

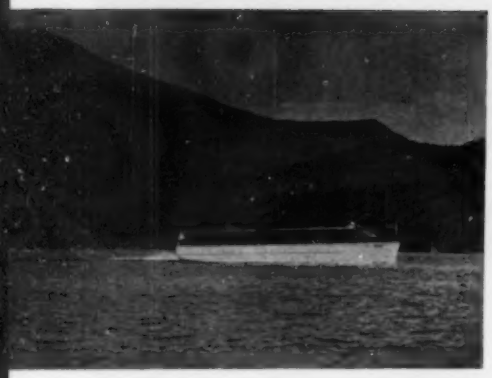
A far cry from international intrigue to parents-teachers meetings, but the principle is the same, need for competence just as great. W. R. Collings, vice president and general manager, Dow Corning, draws on his experience as a citizen of Midland, Mich., to show the engineer as a community citizen. An executive must be a good citizen of his community, a hard-working citizen. How does the engineer stack up in this respect?

The need for the engineer, and his broad competence, in our national defense, as a member of the armed forces, is the subject of Maj. Gen. W. M. Creasy, Chief of the Chemical Corps.

Profitable Atoms

A basic problem of nuclear installations is used-up fuel, what can be done to overcome the economic loss involved? In the symposium of AEC director of reactor development, W. K. Davis, George White, executive vice president, Vitro, and B. V. Coplan (together with J. K. Davidson), Knolls Atomic Power

possibilities in the field may lie in the



Laboratory, General Electric, have the answer—a new chemical industry, nuclear fuel reprocessing.

In all types of nuclear installations the fuel cycle must be lower than the cost of coal to compensate for higher costs elsewhere. Fuel reprocessing could be the answer, and the answer to practical fuel reprocessing is chemical engineering effort to design new processing plants. Can it be done? Both White and Coplan think so. But there are many engineering and economic problems to solve. One thing is sure, it could lead to a new industry, many new jobs for chemical engineers.

Nuclear energy is now in industry. That means profit problems, applications, and risk. Minimizing risk has long been the job of insurance. M. M. Braidech, research director, National Board of Underwriters, and member of the special insurance team that recently completed an AEC approved three-month study of AEC installations, is ready to show what atomic management must expect in the area of risk protection, what management and engineers must do to help minimize risk and cost of insurance. Problems are many, big engineering factors are involved, but the job can be done, despite the dangers in even the smallest leakage, and the hazard of "third-party-liability."

The investigation of new applications is a major concern of engineers in the nuclear field. An important experiment going on now is the attempt to control insect infestation with gamma irradiation. L. E. Brownell, supervisor, Fission Products Laboratory, Univ. of Michigan, and two co-workers, analyze the technical details, emphasize costs, problems with gamma irradiation.

Integration and Growth

To integrate or not to integrate—that is a major chemical management question today. Top level stuff? Yes, but it affects every engineer in his work—in patents, job security, advancement potential, etc.

On the theoretical side of the problem raised by this symposium chairmaned by F. M. Simpson, vice president and general manager, Petroleum Chemicals, Inc., J. G. McLean, Harvard Graduate School, and R. B. Schneider, vice president, Chemical Department, Empire Trust Company, analyze the broad pros and cons. Integration has played a major role in the growth of the oil industry for many reasons that McLean will bring out, but now it is growing more and more important in the chemical field. Taking the chemical industry, Schneider tells what is behind the near-epidemic of mergers and acquisitions, why, is it really doing the job intended, where is it going from here? Are all the facts of integration on the plus side? Schneider says no, and he will explain the dangers involved.

And what does integration do to the engineer in the company? There are bound to be dislocations, personnel problems, and many other matters that affect the engineer. To throw some light on these problems, and on the specific complications of integration, S. A. Swensrud, chairman of the board, Gulf Oil, will give a case history of Gulf's growth into one of the most fully-integrated oil companies, and W. P. Gage, president, Grace Chemical Research & Development Company Division, will do the same for W. R. Grace in the chemical industry. Grace is of particular interest as a company originally in shipping and banking. Merging with Davidson and Dewy & Almy, expanding its own facilities, Grace has integrated in the chemical field until it is a major chemical company. How it was done and why is a vital question for engineers and management.

Economy and Power

Basically, the chemical industry is in a period of careful consideration of the operating economy and flexibility of power sources, is basing much relocation and new plant building on the availability of new gaseous and low-grade fuels. Expanding on this theme, G. C. Woodard, assistant general sales manager, Cooper Bessemer, will show the symposium on "Packaged Power," led by H. A. Martin, executive vice president, J. F. Pritchard, how the efficiency of new prime movers may influence all future building and moving, may even influence process design itself.

With costs of power so important, and the chemical industry always looking for special power sources, the symposium will investigate some prime new possibilities in detail. E. G. Beardsley, vice president, Clark Bros., takes up the turbo-supercharged 2-cycle gas engine. Will its obvious advantages as a fuel saver outweigh such defects as difficult start-up? And what about the industrial potential of the gas turbine? A. A. Hafer, manager of production planning and market research, Gas Turbine Department, General Electric, shows the gas turbine's potential special advantages for the chemical industry—large quantities of compressed air, heat for processes, highly pre-heated combustion air, all in addition to shaft power.

An example of the search into special power sources is the look the symposium is going to get at the possibilities for industry in small gas turbines. P. L. Ward, manager of turbine and control sales, Solar Aircraft, thinks the small turbine has a definite future in industry, tells why, will back it up, too.

The Future

Industry's stake in the future of atomic energy has been analyzed, but what about the engineer's personal possibilities? Joining symposium chairman, J. A. Thornton, president, Lummus Co., C. R. McCullough, assistant director of Development Research and Engineering, Monsanto, looks at the future in nuclear engineering, sees chemical engineers everywhere. Despite everyone trying to get into the act (EJC's Nuclear Congress has backing of no less than 25 engineering societies) McCullough sees the chemical engineer as having the greatest potential usefullness. That is as far as we see it now, but what we see now may be only a scratch on the surface of what the future will hold for atomic energy applications, and McCullough feels the chemical engineer's real

possibilities in the field may lie in the new areas we cannot even think of now.

Travelling on into the future, C. R. De Carlo, director of Applied Science Division, International Business Machines, steps into the field of automatic data handling and computation. First step in complete automation would undoubtedly be complete automation of data handling and computation. Is it here? Will it be soon? It may well be in the operations research field, but what about process control. In that De Carlo agrees with the instrument men (see Roundtable Discussion in this issue), sees two barriers: economic, and informational. The latter is simply a question of do we have sufficient data, and proper data, on processes to enable a machine to control them. Most answers are no, not yet, don't know when we will. But De Carlo will have a lot to say on this.

Walk before you fly—which means "basic training" is still a crucial point for the engineer and industry. Dean J. C. Elgin, School of Engineering, Princeton, will look far ahead into the ever advancing field of the engineering curriculum. Is a revolution in the offing? Perhaps. Elgin, at least, sees the future as belonging to the chemical engineer-scientist, not the engineer-technician. What is going to happen to the unit operation? A lot, Elgin thinks, explaining what is challenging it these days. So much is changing that it is possible there will be only one science of engineering in the year 2000.

Anchor-man B. K. Brown, president, Pan Am Southern Corp., is going way out on a limb. What is the chemical engineer as a person and as an engineer going to be like in the next ten or twenty years? Genius? Of course. But what else? Frankly, we don't know any more than you do. But after Brown goes over all the discussions of the whole meeting, talks to engineers, educators, and industry leaders, cogitates, and quizzes his crystal ball, we'll find out. Don't know about you, but we can hardly wait.

Relaxation, Too

Well, there it is. We predict it'll keep you pretty busy, but not too busy, we hope. There'll be hours of informal chatting to do with the speakers and members, but you can do that while playing golf, riding, etc. And we doubt if you'll be able to resist this chance for summer-end relaxation, with the wife and professional friends. Maybe the best bet is to plan to hang around with the others for a few more days after the meeting is over, get more inside information, more of everything Lake Placid has to offer—you couldn't possibly get it all, but we think it's worth a good try.

HOW TO GET THERE

By Rail:

The New York Central operates two through-pullmans each day from New York City.

From the West connections for the New York Central can be made at Chicago, Peoria, Cairo, St. Louis, Cincinnati, and Indianapolis direct to Utica, N. Y., where the Lake Placid train can be secured. However, through pullman service to Lake Placid can be had only from New York City.

From the South, connections can be made at Pittsburgh, Cincinnati, and New York. Through pullman service from New York only.

From New England, connections are made at New York or Albany. Pullman service is available.

The Delaware & Hudson runs two trains per day from New York to Westport, N. Y., where auto transportation to Lake Placid is available by notifying the Lake Placid Club when making hotel reservations.

By Air:

Colonial Airlines operates three flights a day from New York City to Lake Placid—two of these available from Albany. American, TWA and Mohawk also operate flights. Flying time: 2 hours.

TECHNICAL PROGRAM

MONDAY, SEPTEMBER 26, 1955

SYMPOSIUM ON "PACKAGED POWER"—H. Arthur Martin, Chmn.

The Turbo-Supercharged Two-Cycle Gas Engine, E. G. Beardsley, Clark Bros., Olean, N. Y.

The Gas Turbine and its Application in the Chemical Industry, A. A. Hafer, General Electric Co., Schenectady, N. Y.

Has The Small Gas Turbine An Industrial Future? P. L. Ward, Solar Aircraft Co., San Diego, Calif.

The High Efficiency Engine as a Compressor Drive, G. C. Woodard, Cooper-Bessemer Corp., Mt. Vernon, O.

SYMPOSIUM ON "BROAD SOCIAL COMPETENCE OF ENGINEERS"—J. Donovan, Chmn.

Military Engineers' Contribution to our National Strength, Maj. Gen. W. M. Creasy, U. S. Army, Washington, D. C.

Engineers and Scientists Participate in Community Activity, W. R. Collings, Dow Corning Corp., Midland, Mich.

Management Encourages Engineers to a Broader Life, R. K. Gottshall, Atlas Powder Co., Wilmington, Del.

Engineering Participation in International Negotiations, H. W. Page, Standard Oil Co. (N. J.), New York, N. Y.

TUESDAY, SEPTEMBER 27, 1955

SYMPOSIUM ON "ATOMS FOR PROFIT"—W. K. Davis, Chmn.

The Problem of Insurance in Atomic Energy Developments, M. M. Braidech, National Board of Fire Underwriters, New York, N. Y.

The Design of a Gamma Irradiation Facility for the Control of Insect Infestation in Flour, Meal or Grain, L. E. Brownell, J. J. Bulmer and J. V. Nehemias, University of Michigan, Ann Arbor, Mich.

The Fuel Reprocessing Factor in Nuclear Power, George White, Vitro Corporation of America, New York, N. Y.

Reactor Fuel Processing—A New Chemical Business? B. V. Coplan, and J. K. Davidson, Knolls Atomic Power Laboratory, Schenectady, N. Y.

WEDNESDAY, SEPTEMBER 28, 1955

SYMPOSIUM ON "GROWTH OF THE OIL AND CHEMICAL INDUSTRY BY INTEGRATION"—F. M. Simpson, Chmn.

Integration in the Oil Industry, J. G. McLean, Harvard University Graduate School, Cambridge, Mass.

Integration in the Chemical Industry, R. B. Schneider, Empire Trust Co., New York, N. Y.

Growth By Integration, Gulf Oil—A Case History, S. A. Swensrud, Gulf Oil Corp., Pittsburgh, Pa.

Growth By Integration, W. R. Grace & Co.—A Case History, W. P. Gage, Grace Chemical Research & Development Co., New York, N. Y.

SYMPOSIUM ON CHEMICAL ENGINEERING ORGANIZATIONS OF THE FUTURE—J. F. Thornton, Chmn.

Educating the Chemical Engineer of the Future, J. C. Elgin, School of Engineering, Princeton University, Princeton, N. J.

The Future of Automatic Information Handling in Chemical Engineering, C. R. De Carlo, International Business Machine Corp., New York, N. Y.

The Future Relationship Between Chemical and Nuclear Engineering, C. R. McCullough, Monsanto Chemical Co., St. Louis, Mo.

What May We Expect of Chemical Engineers in the Future? B. K. Brown, Pan-Am Southern Corp., New Orleans, La.

SOCIAL—RECREATIONAL PROGRAM

SUNDAY, SEPTEMBER 25, 1955

Cocktail Party, 5:00 P.M.

Buffet Supper, 7:00 P.M.

MONDAY, SEPTEMBER 26, 1955

Luncheon, 12:30 P.M.

Sight-seeing Tour, Summit House, Whiteface Mt., 2:00 P.M.

Sight-seeing Tour, Ausable Chasm, 2:00 P.M.

Banquet, 7:00 P.M., Speaker—H. F. Smiddy, Vice President & Manager, Management Consultation Services, General Electric Company, New York, N. Y. Subject—Development of Professional Managers.

TUESDAY, SEPTEMBER 27, 1955

Luncheon, 12:30 P.M.

Golf Tournament, 2:00 P.M.

Sight-seeing Tour, Summit House, Whiteface Mt., 2:00 P.M.

Sight-seeing Tour, Ausable Chasm, 2:00 P.M.

Dinner, 7:00 P.M., Golf Trophies presented

Movies, 9:00 P.M.

WEDNESDAY, SEPTEMBER 28, 1955

Luncheon, 12:30 P.M.

Sight-seeing Tour, Boat trip around Lake Placid, 10:00 A.M.

SPECIAL LADIES EVENTS

Ladies are invited to all luncheons and other events on the general program.

MONDAY, SEPTEMBER 26, 1955

Special Breakfast, 8:30 A.M.
Guided Tour of Club, 10:00 A.M.

TUESDAY, SEPTEMBER 27, 1955

Breakfast, 8:00 A.M.
Putting Tournament, 10:00 A.M.

WEDNESDAY, SEPTEMBER 28, 1955

Breakfast, 8:00 A.M.
Bridge-Canasta Party, 2:30 P.M.

UNIQUE STRESS-RELIEVING

On giant construction at Sun Oil

Stress relieving complete reactor sections of two giant Houdriflow units built recently for Sun Oil was done over 160 feet in the air.

Faced with the problem of stress relieving the reactor sections of the units built for Sun at Marcus Hook, Pa., and Toledo, Ohio, after they had been raised to position and welded, Catalytic Construction and Chicago Bridge & Iron employed a 40,000 pound portable hot air furnace mounted on the stair tower some 160 feet above the ground. The furnace has a capacity of 20 million B.t.u. per hour, was equipped with a blower of 50,000 CFM capacity. Once the unit was up, hot air was blown through it from the furnace on the stair tower and stress relieving performed from the inside.

This unique operation was only one of many engineering feats on these giant construction jobs. The derricks used to raise the tower sections are believed to be the highest pedestal-type guy derricks ever used—overall height, 442 feet.

Physical size of the main vessels made it necessary to assemble them in the field on the ground, stress relieve 13 sections of each unit in a temporary furnace erected next to the units, lift them on the derricks, and weld in place. It was necessary to lift the sections high into the air to clear the 2¼-inch guy wires. Most difficult lift—94-ton cooling coil section 300 feet into the air.

Unit ready for reactor section to be lifted in place. Portable stress-relieving furnace mounted (within circle) on stair tower.

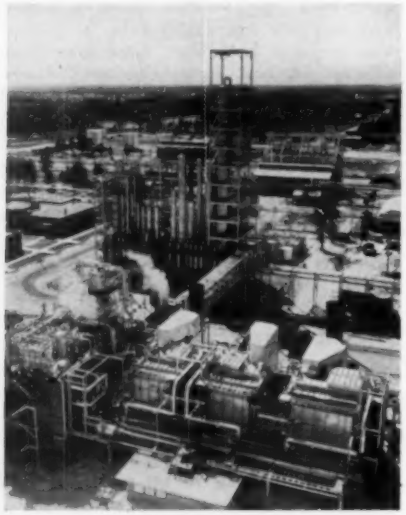
High lift of tower section by 442-ft. derrick necessary to clear guy-wires.

All of the main seams in the regenerator and reactor portions of the units were x-rayed, with as many as three x-ray units employed at one time on each job. Some of the thicknesses x-rayed were 2⅜-inches thick.

Each job took some 610,000 man-hours over an 11½-month period.

MORE OXO

—in Texas



Expansion of Texas Eastman's Oxo plant at Longview, Texas, is now underway. Rapidly increasing demand for products that depend on the "butyl family" is reason for step. New facilities will also permit production of other chemicals in addition to the butyls, such as propyl aldehydes and derivatives, anyl aldehydes, and decyl aldehydes. □

MANY BY SEA

—Bulk Chemicals Go By Water

Continuing to grow is the now highly popular transportation method of shipping heretofore land-bound bulk chemicals by water.

Most important recent development in the water-borne chemicals field is the use of a new tanker run from Gulf Coast ports to the Eastern seaboard. The 16,000-ton tanker *S.S. Chemical Transporter,* makes its complete run in about 9 days, carries various chemicals for four major companies.

Monsanto—Shipping molten sulfur on the high seas for the first time.

Columbia-Southern—Shipping caustic soda on all trips of the ship.

Commercial Solvents—Large quantities of methanol.

Celanese Corporation—Will ship fifteen different chemicals, ranging from acetone and alcohols, to formaldehyde and acetic acid.

The ship is owned and operated by Chemical Tankers, Inc.

Not as spectacular, but steadily growing, is the use of special barges for chemical transportation. Latest entry: Two special barges to be used by Diamond Alkali to carry caustic from Houston to Tuscaloosa, Alabama.

But what is carried must be unloaded, and the dock builders are hard at work on this end. Newest contracts are Dravo Corporation's agreements with Barrett Division, Allied Chemical, to construct a liquid cargo dock on the Ohio River at Ironton, Ohio, and with American Synthetic Rubber Co. to construct another liquid cargo dock at Louisville, Ky.

Further expansion of American instrumentation in foreign countries is the result of a new agreement between The Foxboro Company, Foxboro, Mass., and the Yokogawa Electric Works, Ltd., Tokyo, Japan. The Japanese company will manufacture and sell the full line of Foxboro instruments as well as its own electric strip chart instruments. □

Polyethylene molding and extrusion materials are being produced in a new plant of Dow Chemical now in full production at Freeport, Texas. The process is licensed from Imperial Chemical Industries, Ltd., but Dow has modified both process and equipment as a result of its own research and pilot plant work. □

Over 6 Million Tons of
SULFURIC ACID*

produced annually in plants designed and built by CHEMICO

More than 165 Chemico H_2SO_4 plants are today in operation all over the world

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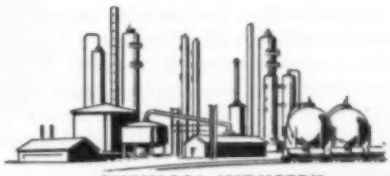
FERTILIZER INDUSTRY

RUBBER INDUSTRY

MINING INDUSTRY



CHEMICAL INDUSTRY

STEEL INDUSTRY

TEXTILE INDUSTRY

*Chemico-designed plants now under construction will have an additional annual capacity of 500,000 tons of sulfuric acid by the end of 1955.

CHEMICAL CONSTRUCTION CORPORATION

A UNIT OF AMERICAN CYANAMID COMPANY

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PUMP USERS QUIZZED

A.I.Ch.E. Committee questions chemical industry pump users, gets likes and dislikes, needs and gripes.

Designed to furnish a general indication of what is wanted by pump users, a questionnaire circulated and tabulated by A.I.Ch.E.'s Subcommittee on Pumps, under the chairmanship of R. L. Jacks, points the way to better pump service for the chemical industry.

Generally, picture is one of satisfaction on the part of the users of pumps in process industries, but shows much work to be done, many areas of good work already being done, clearly indicates where study is needed.

Seeking the answer to the growing problem of standardization of equipment as it affects pumps, the Committee quizzed users in some detail, found considerable disagreement. At present some 42% do use a standard form of their own, setting forth basic data to be used by pump manufacturers in quoting on the users' pump requirements, while 58% don't—a fairly even split. Of those who do not use such a form, 76% would use a standard one prepared by A.I. Ch.E., and of those who do use such a form, 80% would use the A.I.Ch.E. form. In short, most of those who do try to have a specific standard for their pumps, and most of those who don't at present, would be ready to use a general standard.

Only 57% feel there is an adequate agreement on chemical pump parts terminology and nomenclature, and 85% feel a standard "dictionary" is needed. In addition, 90% think there should be a better guide or handbook for materials of pump construction.

In the more specific matter of definite and universal standards for the various parts of all pumps, there is again disagreement. In general, three-fourths of those quizzed showed a definite interest in the idea of specific standards for such parts and requirements as baseplates, bolt hole dimensions, maximum eccentricity of shaft, minimum bearing life, and many others. But there was a strong undercurrent from the pump users that such standards are not really feasible, that too many special conditions are involved with each particular installation. The final consensus was that the lack of standards, while sometimes creating problems, did not, as far as the majority was concerned, interfere with the selection or use of the pumps. Nevertheless, the majority indicated a willingness to cooperate in an attempt to establish standards.

Performance

For the most part 92% of the pump users who answered the questionnaire are quite satisfied with pump performances based on testing with water. But there was a strong feeling that if a pump is for a specific liquid its performance curve should be based on that liquid. Greatest need seemed to be in the area of viscous liquids, where 72% felt there was a need for more data on pump performance. It was clear that there is a strong concept that much basic research is needed in the area of handling viscous liquids with pumps.

As far as pump design goes, most users questioned showed general satisfaction with present mechanical seals of all types, found them to last a reasonable length of time. Most seemed to agree that present pumps are doing an adequate job for them. The main problem seems to be in packingless pumps, where 81% expressed a need for them, 79% were not satisfied with present ones. Trouble is a need for more rugged pumps of this type, with less expensive mechanical seals to handle a greater variety of corrosive liquids at higher heads and in greater capacities.

What Users Want

Expressions of needs that users seem to feel are not fully satisfied at present usually included the following points:

1) Better mechanical seals more accessible for maintenance.

2) Standardization on about four frame sizes, with standard dimensions for frames and connections.

3) Adoption of limited number of mechanical seals or packing sizes.

4) Good all-purpose explosion-proof pump at reasonable cost.

5) High efficiency, low capacity, high head centrifugal pump to operate at 1750 r.p.m.

6) More protection of baseplate and frame against corrosion.

7) Universal use of coupling guards.

8) More attention to shaft deflection and bearing life.

9) Interchangeability of parts between different sizes of pumps of the same manufacturer.

But in general the answers indicated that present pumps, all in all, are doing good jobs. Objections were largely on specific problems of specific users, more in the nature of suggestions for working closer to perfection rather than indications of present dissatisfaction. Criticism was definitely in a constructive vein, and a willingness was indicated to help the pump manufacturer find ways to give better service.

New handling system for bulk polyethylene has been designed around the use of giant, collapsible synthetic rubber containers (9400 pounds net per container). In use at Bakelite Company, a division of Union Carbide, the new containers are designed to save up to one-third cent per pound shipped by reducing bulk handling costs, resin losses, and storage space requirements, will also help maintain higher product quality by keeping out dust, dirt and other contaminents.

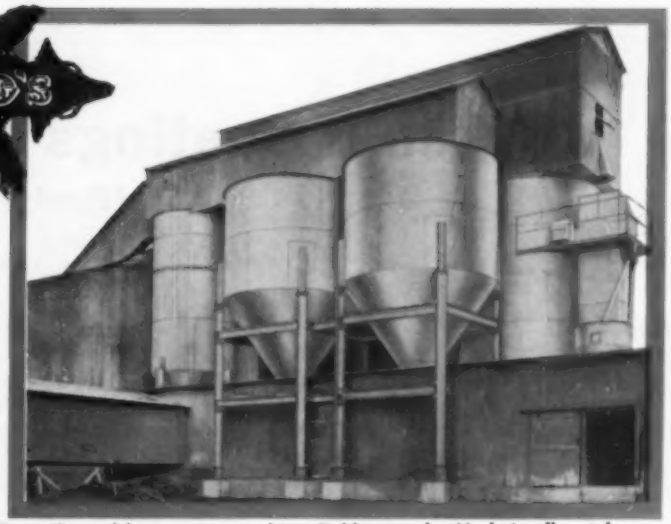
The containers can be stored in little space, can be stored outdoors, are easily cleaned, relatively puncture proof, and will not contaminate the resin. By being adaptable to mechanical handling, the containers simplify and speed-up handling operations. □

An economically produced pump to handle radioactive fluids as easily as pumps now handle chemicals, is one of the major goals of Byron Jackson Company's expansion of its Mechanical Seal Product Division.

Visualizing a rapidly expanding market for mechanical seals on pumps, Jackson has refitted its mechanical seal laboratory, reorganized and expanded, to grapple with some of the most difficult problems of pumping engineers, problems involving extremes in pressure, temperature, and corrosion. Biggest potential goal is the pumper's major headache—the handling of high pressure, high temperature radioactive fluids. □

Sharples Chemicals Inc. is now an operating division of the Pennsylvania Salt Manufacturing Company.

BACK IN THE 1880's

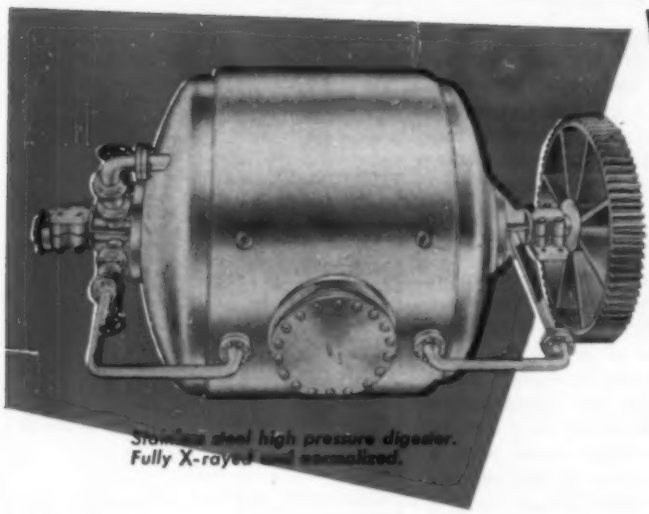


Conical bottom storage bins. Field erected. Made in all metals.

WHEN THE AMERICAN INDIANS BECAME UNITED STATES CITIZENS

Koven

WAS MAKING INDIVIDUALIZED CHEMICAL EQUIPMENT



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Organic Coatings Indicator Chart
(Part I)

Kenneth Tator K.T.A. Associates, Coraopolis, Pa.

Purpose: To present concisely and compactly that basic information required to direct the chemical engineer toward those organic coating types which are most promising in physical characteristics and resistances for solution of his problems.

Limitations in Use: Any such condensation of the vast accumulation of data on the many existing organic coating materials, and generalizations presented in such condensations necessarily will have exceptions. Performances indicated represent only typical and average performances of related groups, and individual material performances within any such group may deviate markedly from the performances here indicated as representative of that group.

For these reasons this presentation is entitled a "coating indicator," rather than a "material selector." Final selection of materials best suited for any coating use must be on the basis of end use details not possible to include in a generalized presentation such as this.

Limitations in Scope: This presentation is directed primarily to organic corrosion barriers: protective coatings, linings, and coverings. Where such materials are also available in the forms of unsupported fabrications, moldings, and extrusions this fact is indicated, but no attempt has been made here to make the presentation complete for all materials in current industrial use in these latter capacities.

Even within use as organic barrier materials only those material types have been considered which are in widespread industrial use. Performance data on such materials as the isocyanates, fluocarbons, Hypalon, and many others of the new and currently less frequently used materials are available and could be fitted into this presentation.

Definitions:

Oil-Base—Organic coatings which contain in part a drying oil or derivative of drying oil, free or in combination. Thus, these include alkyds and epoxy esters, as well as oleo resinous and straight oil paints.

Reactive Materials—All barrier materials which must undergo a chemical reaction during or after application to attain their ultimate resistances and other useful physical properties. Included are oil-base paints which dry by oxidation, vulcanizable rubbers, materials such as the thermosetting resins which further polymerize under action of catalysts or heat, and silicate coatings made insoluble by reaction with metal ions.

Plastic—Organic materials which are reversibly softened by application of heat, and of which the dry film or coating deposited by evaporation of the solvents can at any subsequent time be redissolved by those same solvents.

Numerical Ratings in Chart

The numerical ratings shown in sections 2 and 3 of the chart represent only the relative progressive order in which the various coating types worsen. These gradings have no quantitative significance. A rating of 4 simply means that material types with a 4 rating are worse in this respect than material types which have a rating of 3 or less, and better than material types which have a rating of 5 or greater. It should be appreciated that such ratings are approximate and represent average performances for the material class. Individual materials within any class may vary as much as two units from the average shown.

Material Selection

Five steps are necessary in order to select properly those materials most conducive to optimum performance for any problem. A preliminary step not included in these five is that the chemical engineer should be acquainted with the expected conditions of use. These five steps are as follows:

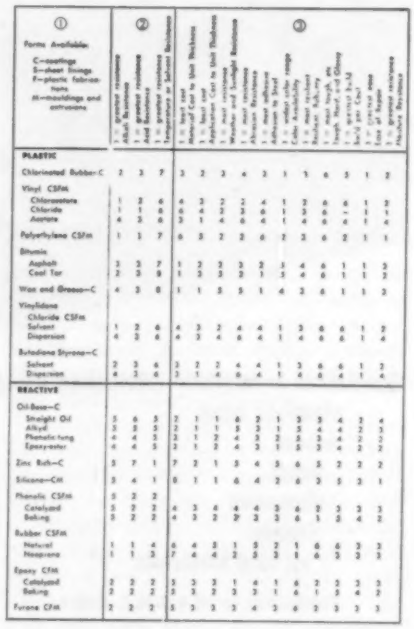
1. Refer to reactive and plastic listings and by means of relative orders of resistance shown in (2) select the material or material groups which include materials having desired resistance to organic solvents, acids, alkalis, and elevated temperatures.

2. For those material types selected in first step choose from (3) those materials which have optimum characteristics for your special requirements.

3. Thus after a determination is made of the material types most conducive to successful performance, review the descriptive paragraphs for these types to verify suitability for the intended use.

4. Having thus determined theoretical suitability of material types for the use, call in technical representatives of material manufacturers producing those favored types and consult with them regarding the best individual formulation within the type.

5. Having thus selected the most promising formulations for the problem, test these formulations in actual exposure use, applying each of the selected formulations exactly according to the quality and methods which will prevail in practice.

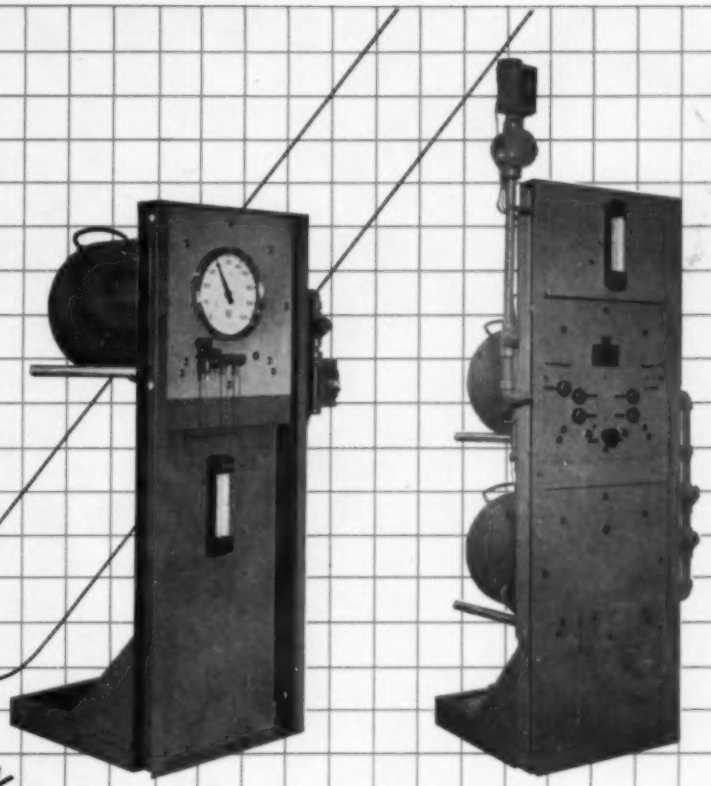


Above is a reduced version of the Indicator Chart to appear full size in Part II, September, C.E.P.

throughput up

quality up

costs down



process refractometer

(Type 38-201)

Monitors or automatically controls a process stream by *continuously* comparing its refractive index (the measure of the velocity of light through the test fluid compared to its velocity through a vacuum) with the index of a sample of *desired* composition. SEND FOR BULLETIN CEC 1839-X10.

infrared analyzer

(Type 38-101)

Handles up to five streams at a rate of 5 analyses per hour, i.e., 12-minute cycle. Increases fractionator capacity by minimizing fluctuations and holding product composition steady. Eliminates the time lag inherent in sampling and batch analysis. SEND FOR BULLETIN CEC 1840-X10.

Here are the first "Consolidated-Phillips" *continuous* process analyzers . . . units which provide analytical data while it's valid, *before* variables have changed. With these two instruments on stream, product quality and production go up . . . costs go down. You can install and maintain them for less, on an hourly basis, than a laboratory technician's salary. Both instruments are completely explosion- and weather-proof.

Consolidated-Phillips process analyzers have been proving their ability . . . and dependability . . . under actual plant conditions for several years. Originally designed and formerly manufactured by Phillips Petroleum Company, they are now backed by Consolidated Engineering's nationwide service organization . . . assurance of interruption-free operation for years to come at the pace demanded by modern refinery practice.

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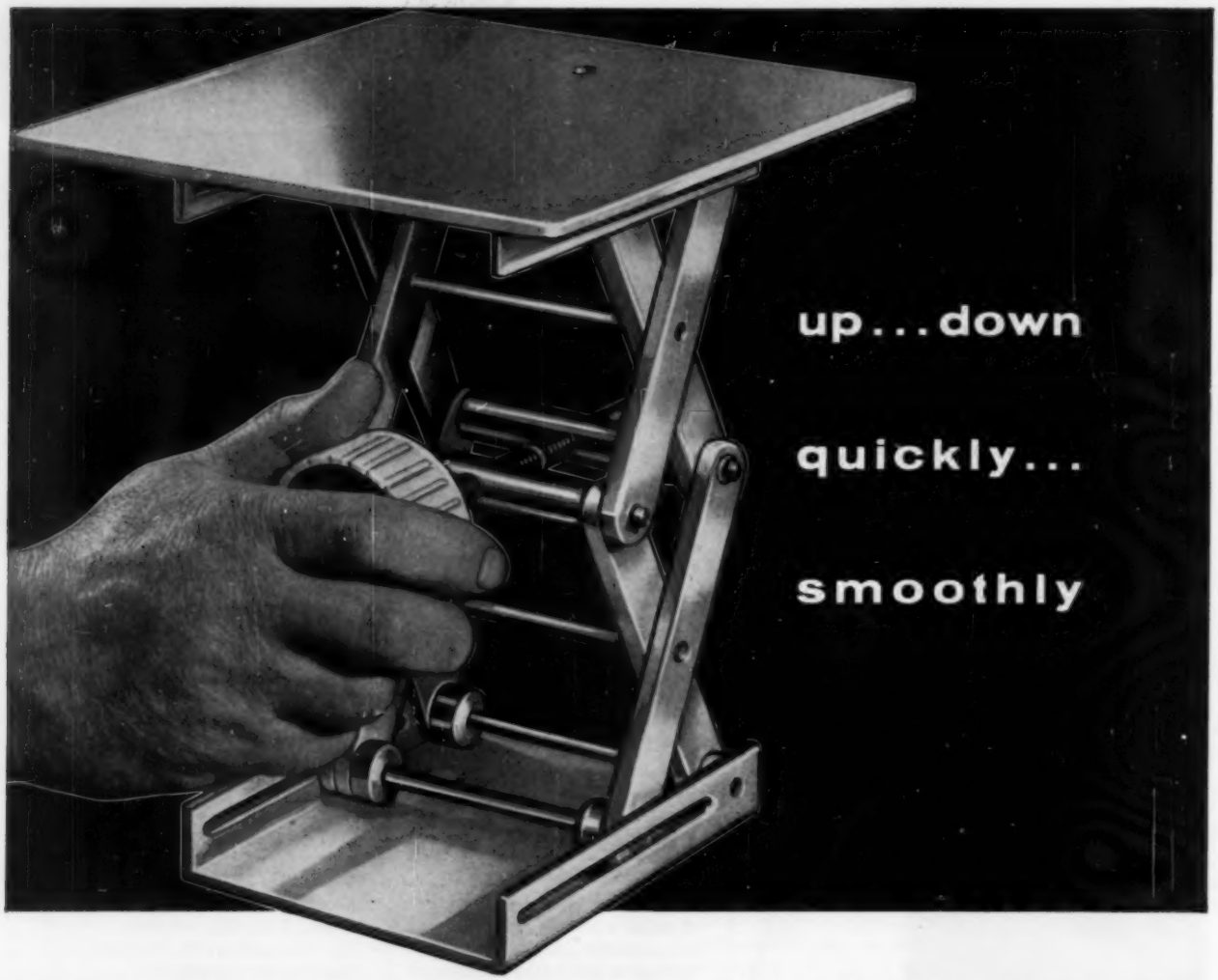

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This all-purpose general utility support is quickly adjustable through an elevation range of 7 inches and will support up to 100 lbs. weight. It operates smoothly without jolts or jerks . . . saves time . . . prevents breakage . . . insures precision . . . particularly useful in isotope research. Ideal for supporting hot plates, oil baths, large Dewar flasks, ground joint glassware, receivers, etc.

The Cenco-Lerner Lab-Jack is made of aluminum and stainless steel with large plastic control knob. Top plate, 5½" x 4¾". Included also is an 8" x 8" auxiliary top plate and support rod for use when larger area is required.

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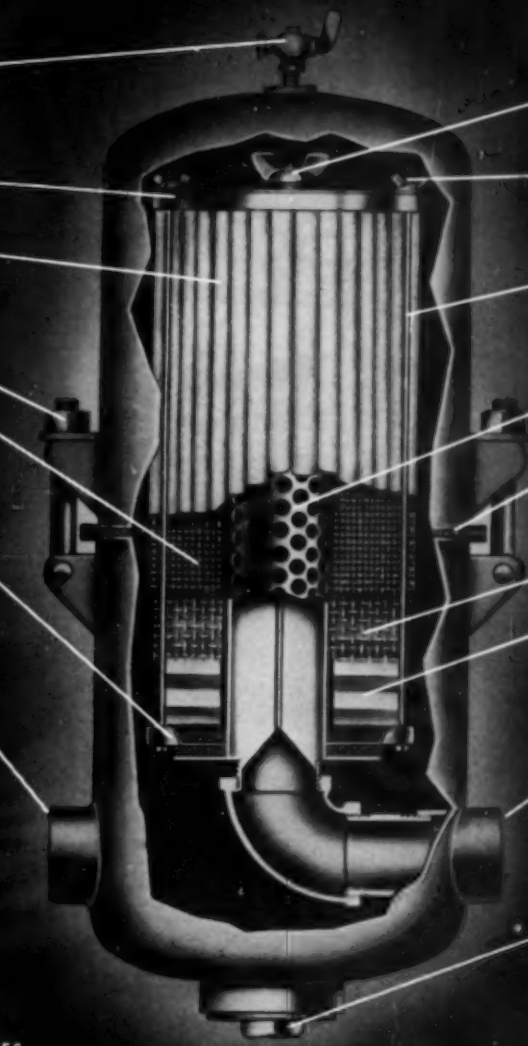

Dollinger engineers welcome your filtration problems. Their complete engineering, design and laboratory facilities are at your disposal. Consult them; no obligation. Write today for new liquid filter folder D-1L.

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THE ANSWER TO YOUR LIQUID FILTRATION PROBLEMS

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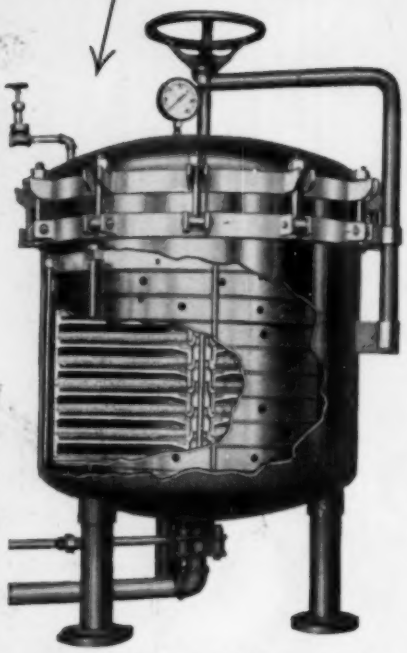
SPARKLER HORIZONTAL PLATE FILTERS



Versatile adaptability make this filter the logical choice of filtration engineers for difficult filtering problems.

Every filtering job usually presents an individual problem involving a combination of various kinds of screens, papers and filter aid. Frequently temperatures are encountered that call for a brine or steam jacketed tank. Linings; plastic or rubber may be needed, with tank and plate metals to fit the product such as mild steel, monel, nickel, stainless steel, bronze or Hastelloy. Constructed to meet ASME specifications when required.

All these structural and material combinations are easily achieved with the Sparkler Horizontal Plate filter.

No fibrous adhesive material is ever required to hold the filter cake on the horizontal plate. The cake is firmly supported on the plate with no danger of cracking or slipping even with a variation in pressure or a complete shutdown in the filtering operation. The patented Sparkler scavenger plate filters almost the last drop in a batch, and allows practically a complete recovery of the product.

Constant filtering quality is maintained from start to the end of the cycle, no break through can occur in a Sparkler Horizontal Plate filter.

What other filter can match this versatility and positive performance under a wide variation of filtering conditions?

Place your filtering problem in the hands of our filtration engineers. They have developed many successful methods of filtering difficult materials and may be able to prescribe a solution to your problem without wasteful experimentation.

Write Eric Anderson for personal attention

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BECKMAN GOES "CONTINUOUS" INFRA-RED

—Buys Liston-Becker

Purchase of Liston-Becker Instrument Co. by Beckman Instruments, Inc. brings Beckman into the field of continuous infrared gas analyzers. Already an important company in the process control and instrumentation field, Beckman, located in Fullerton, Calif., has now expanded into a new area.

By buying the Springdale, Conn., firm, Beckman acquires a series of products which complement its present line, primarily the infrared gas analyzers used for automatic monitoring and control of processes in chemical and petroleum plants, and a specialized electronic amplifier of high sensitivity.

Liston-Becker will operate as a division under the same management and in the same location. At present, The Foxboro Company, Foxboro, Mass., is also offering the Liston-Becker infrared analyzer as part of a complete "packaged" gas analysis system, apparently will continue to do so at least for the immediate future. □

A wire filter cloth having 200,000 interstices (openings) per square inch has been developed by Unique Wire Weaving Company, Hillside, N. J.

Marketed under the trade name, Unique Micronic filter cloth, the new cloth is claimed to be the finest wire cloth woven, obtaining its fine weave without loss of durability or strength. □

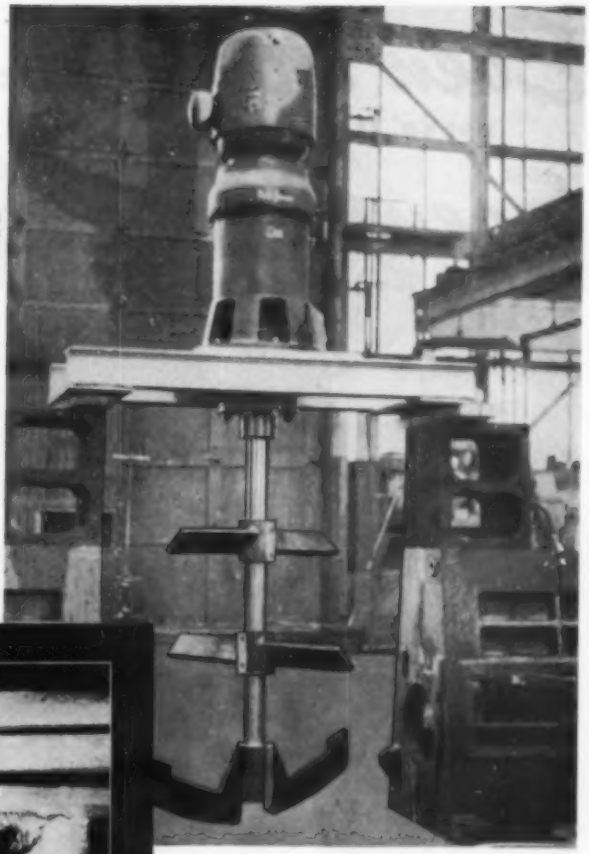
By weighing the compounding tank continuously as each latex is added, a 50% speed-up in the compounding of natural rubber latex with synthetic lattices has been gained by Naugatuck Chemical Company, division of U. S. Rubber Company. Instead of measuring one latex volumetrically, weighing two or more others in small batches and adding manually, a 4,000-gallon tank is supported on three Baldwin SR-4 load cells which sense weight changes electrically and transmit signals that are totalled automatically on the scale of a direct-reading null-balance indicator also made by Baldwin-Lima-Hamilton. Lattices can now be pumped directly from bulk storage, allowing continuous operation.

An Example of How BETHLEHEM Can Handle Mixing of Difficult Materials

CASE HISTORY OF ATLAS MINERAL PRODUCTS CO.

✔ CONSISTENCY VARIES 200 FOLD

✔ H. P. VARIES ONLY 3 FOLD



Agitator assembly in our shop.

Agitator in operation at the plant of Atlas Mineral Products Co.

The Atlas Mineral Products Company plant at Mertztown, Pennsylvania, had to up the production of a high consistency, asphalt-sulphur mix by increasing the rate of heat transfer in existing equipment. Their kettles were jacketed and agitated by a number of flat-bladed paddles. The obvious step would have been to replace these paddles with an anchor agitator; however, the characteristic of an anchor would be to sharply vary the power demand as the consistency changed 200 fold during processing.

Bethlehem designed an agitator to achieve the necessary mixing with the required increase of heat transfer using a 5 h. p. drive as used previously. This agitator consisted of downflow and upflow paddles plus a modified anchor. For it the power demand varied only three fold with a 200 fold increase in consistency.

Atlas tells us:

"The new system of agitation gives about a 40% better heating rate than before."

"Present power supply is entirely adequate."

This agitator is simply another example of our ability to design and build equipment to process difficult materials such as those of high consistency.

Send us a description of your present or new problems in handling high consistency materials. We shall be pleased to work with you toward their successful solution.

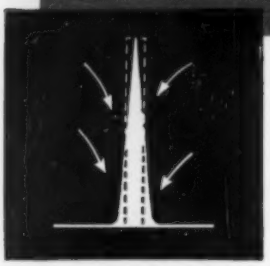
BETHLEHEM FOUNDRY & MACHINE CO.

Bethlehem, Pennsylvania

Even More Surface
per sq. ft. of face area

Even Less
Air Friction

with the New AEROFIN Type B
Smooth-Fin Heat Exchangers



Tapered Fin

The new smooth fin is tapered, with a wide contact base which conducts sufficient heat to make the entire fin effective transfer surface. It is no longer necessary to crimp the fin to provide the required contact area.

By eliminating the air resistance and turbulence caused by the fin corrugations in the old-type coils, it is now possible to use almost twice as many fins per inch with no increase in air friction.

The resulting increase in capacity is obvious. As a consequence, these new coils offer:

Greater capacity per square foot of face area

Lower airway resistance – less power needed to deliver the required C. F. M.

Smaller face area, due to the practical use of higher air velocities

Fewer rows of tubes for a given B.T.U. transfer in a given area

Less weight – easier handling

Better drainage of condensation from water coils; improved venting and drainage for heating coils

Compact, sturdy design

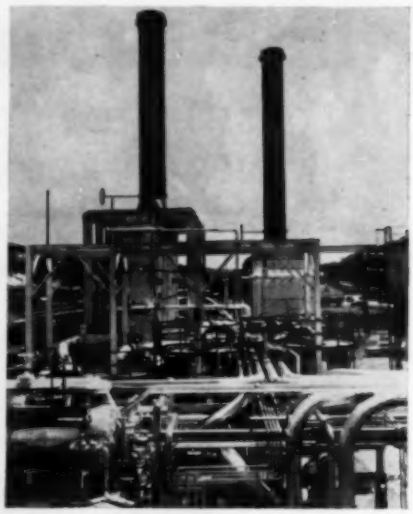
Standardized encased units arranged for quick, economical installation

Aerofin is sold only by manufacturers of fan-system apparatus. List on request.

AEROFIN CORPORATION SYRACUSE 1, N.Y.

INDUSTRIAL NEWS

New 6000-barrels-per-day Houdriformer is now on stream at Ashland Oil & Refining Company's Catlettsburg, Ky., refinery. The unit, complete with guard case pre-treater, will process naphtha fractions of Illinois, Louisiana, and Kentucky crudes.



Licensed in April, 1954, construction was completed by Catalytic Construction Company, Philadelphia, in June. □

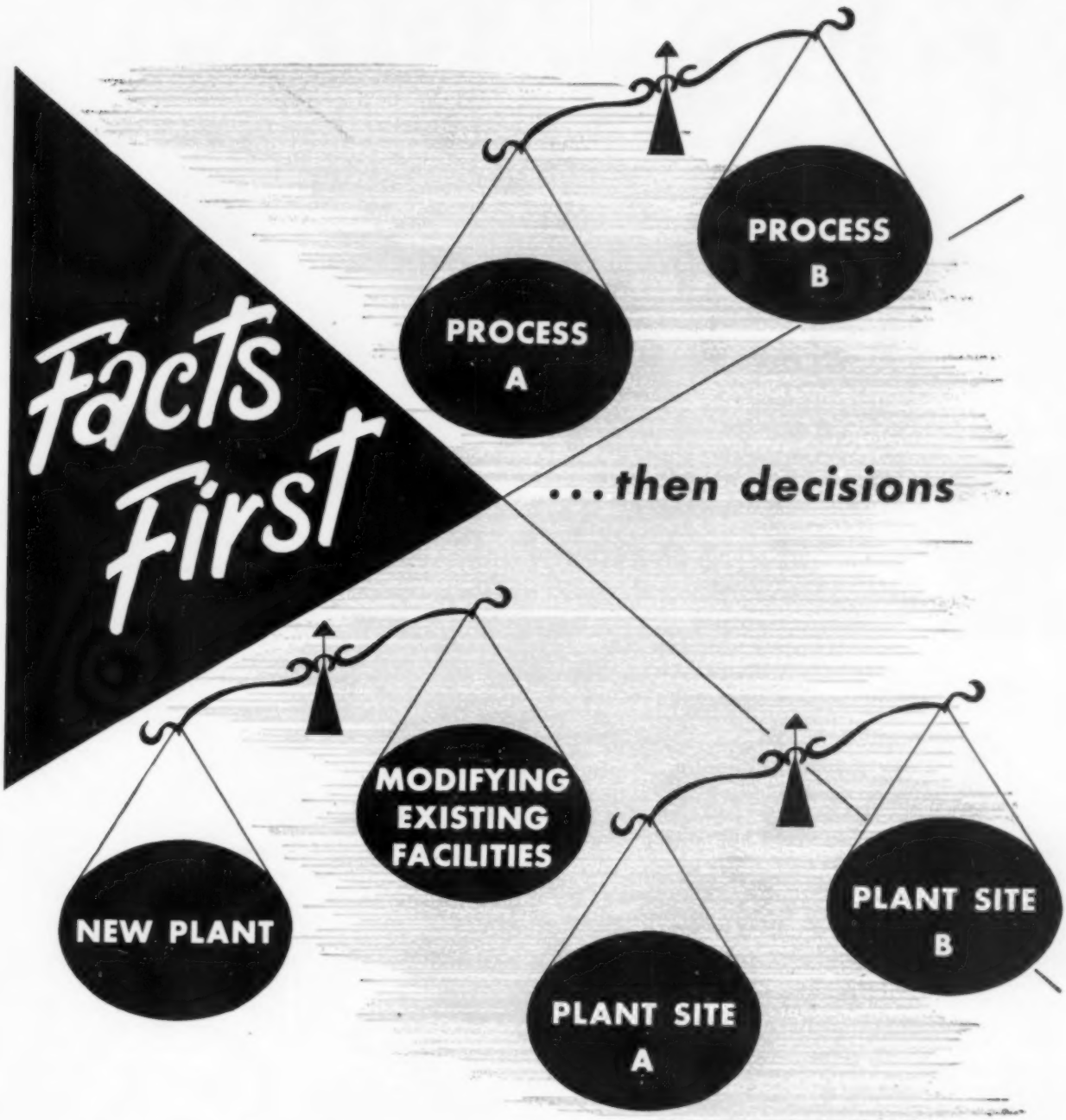
It will pay chemical engineers to keep an eye on the developments of a potentially powerful new process control tool—nuclear magnetic resonance. Perkin-Elmer Corp., Norwalk, Conn., is confident of the importance of the new equipment, has formed a new subsidiary, Nuclear Magnetics Corporation, Boston, to market a complete line.

Expected to find its greatest use in the chemical, petroleum processing, film, and paper fields, the nuclear resonance equipment ties-in directly with Perkin-Elmer's present line of infra-red spectrophotometers and process stream analyzers. □

Now on-stream is second polyvinyl resin plant of National Starch Products, New York. The plant, at Meredosia, Ill., will manufacture adhesives containing large proportions of vinyl emulsions in addition to its primary production of polyvinyl emulsions. □

A case study of production control through electronic data processing, now available, is designed to give business management a better picture of the use of electronic systems.

The study, "Production Control Through Electronic Data Processing: A Case Study," is offered to industry by the Office of Technical Services, Dept. of Commerce. □



Planning to invest large sums in a new plant to manufacture certain products . . . if the evidence indicates it would be profitable?

You will need facts.

Obviously many questions must be raised and reliable answers found before you can make the big No. 1 decision. Your own organization can uncover many of the needed facts. Some work, however, might be handled better by an experienced independent organization. Or such an organization could be used to check important findings of your own.

Here, we can be of service.

We know many processes thoroughly. We know comparative costs and relative merits of competitive processes. We are keenly aware of new developments—both domestic and foreign—in products and probable trends in marketing objectives.

A member of our staff, experienced along such investigating lines, will be glad to discuss your plans in confidence, if you feel we can be of service. A preliminary discussion, of course, does not obligate you in any way.

Engineering

Design and Construction of Process Plants

•

Design and Construction of Process Units

•

Process Evaluations

•

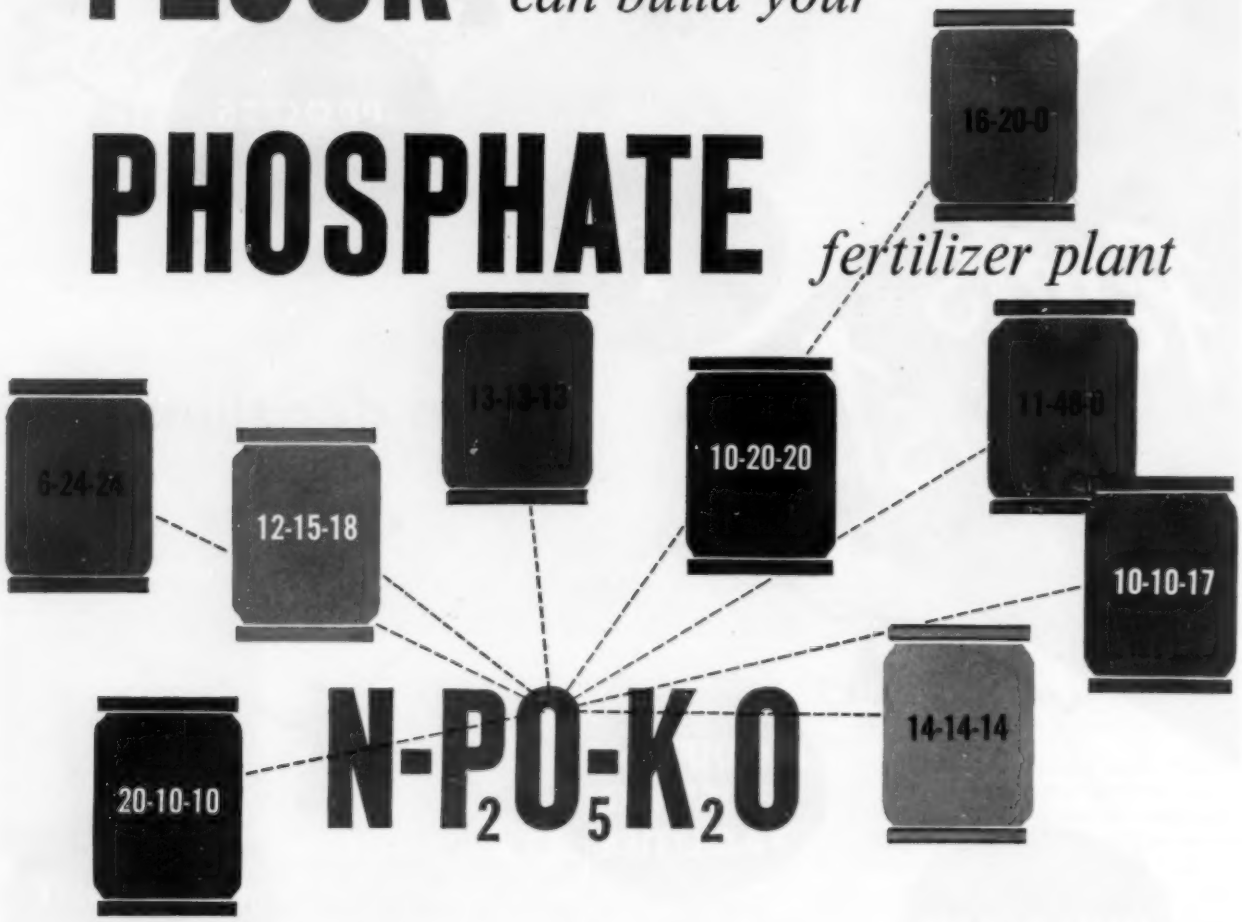
Economic Studies

BADGER MANUFACTURING COMPANY

230 BENT STREET, CAMBRIDGE 41, MASS. 60 EAST 42nd STREET, NEW YORK 17, N.Y.

FLUOR *can build your*

PHOSPHATE *fertilizer plant*



Fluor enters the phosphate fertilizer industry through an exclusive agreement with St. Gobain of France. At a time when few men realized the vast significance of complete fertilization, St. Gobain was developing commercial processes for the manufacture of phosphate fertilizers.

In cooperation with St. Gobain, Fluor designs, engineers and constructs entire plants of any tonnage for the low-cost production of ammonium phosphates, nitric phosphates, limed ammonium nitrate, triple superphosphate, and other complete fertilizers containing nitrogen, phosphorus and potassium. The St. Gobain-U.C.B.* phosphoric acid process presents the latest advancements in phosphate rock acidulation techniques resulting in high yields and low costs.

Products are of superior quality. In particular, granulated ammonium and nitric-phosphate types are homogeneous, hard, and free-flowing materials. Varying degrees of P_2O_5 water solubility may be produced at will for the nitric-phosphate types.

A variety of fertilizer products can be made from a Fluor-designed plant. As the fertilizer market shifts its demand, the same equipment can not only produce several different formulas of the same type, but with only minor changes can be converted to produce new and different types of fertilizers. Investing in a plant that can do the work of two or three is good foresight.

In addition to the many refining and processing facilities for the petroleum, natural gas and chemical industries, Fluor has four anhydrous ammonia plants in various stages of design and construction with a total daily output of 700 tons. Fluor offers better processes and a capable engineering/construction organization to the plant food producers of the United States and Canada. We welcome your inquiry.

BE SURE WITH **FLUOR**

THE FLUOR CORPORATION, LTD.
LOS ANGELES 22, CALIFORNIA, U.S.A.

FLUOR OF CANADA · TORONTO
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AFFILIATES: SINGMASTER & BREYER, NEW YORK; H. G. ACRES & COMPANY, LTD., NIAGARA FALLS, ONTARIO, CANADA

ENGINEERS
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NEW YORK
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BOSTON
PITTSBURGH
SAN FRANCISCO
HOUSTON
BIRMINGHAM
TULSA
DENVER

*Union Chimique Belge.

the chemical engineers'

DATA SERVICE

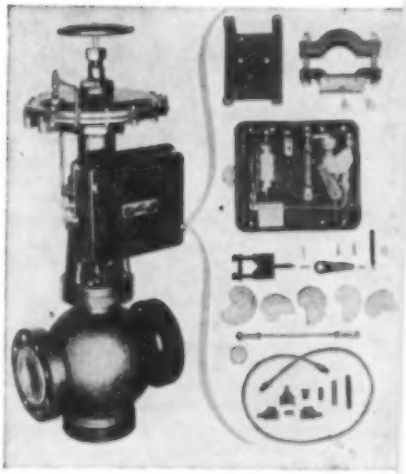
and

GUIDE

to significant developments in

- EQUIPMENT
- MATERIALS
- SERVICES

developments of the month-



50 Solve your valve positioning problems.

New Positioning Relay Kit of Bailey Meter Co. is now available for field application to any air operated control valve. Intended to solve such major valve positioning problems as stuffing box friction load, poor response, unbalanced inner valves, hysteresis, and undesirable regulating characteristics, Bailey expects the relay to have particular application where control valves are integral with control systems. In such cases, the relay maintains stable sensitivity and response, amplifies control signals, and provides sequence operation of two or more valves. Standard SAMA signal ranges of 3-15 lbs./sq.in. gauge, or 3-27 lbs./sq.in. gauge, actuate a force-balance mechanism, as little as 0.065 lbs./sq.in. gauge applies full output to valve motor. Relay is direct or reverse acting, suitable for top or bottom-connected valves. Six preshaped cams are provided for square root, linear, square and half-travel regulating characteristics. For further information circle number 50 on Data post card.

(Continued on page 50)

TURN THIS PAGE TO RIGHT FOR MORE . . .

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Merely encircle numbers on cards to get literature desired. On advertised products in front of magazine, fold this page out to right. For those in back, fold card strip again to right, where card strip is scored for detaching.

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New York 36,
New York

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products-

IFC Waste Utilization. Systems designed & built for translating problems of wastes into opportunities for profits. Vulcan Copper & Supply Co.

3R Packing. Mechanical rocking-vibration motion of ViBrox barrel & drum packer reduces costs, labor, container size, increases quantity packed. B. F. Gump Co.

4-5A Chemical Valves. Lubricated plug valves in complete size range & pressure temperature ratings, variety of materials from Rockwell Mfg. Co.

6L Packing. Teflon packing for manual, air or motor operated valves. Tapered V design offers advantages. United States Gasket Co.

7A Mechanical Seals. Elimination of unnecessary leakage prevents contamination of pumped liquid & other waste. Use Byron Jackson Co. seals.

8A Filtration. Celite filter cakes used in production of antibiotics provides critical purity required. Johns-Manville.

9A Vacuum Dryer. A new use for vacuum dryers, processing of heat-sensitive weedkiller. Engineering & laboratory research knowledge available. F. J. Stokes Machine Co.

10L Chlorination. Slime control equipment built on basis of 40 years experience increases plant efficiency & cuts cost. Wallace & Tiernan.

11A Vacuum Filter. Drum & disc type filters as well as other types for special applications in the process industries. Eimco Corp.

12A Meters. Force-balance accuracy & ruggedness in line of pneumatic transmitters having range flexibility & giving corrosion protection. Republic Flow Meters Co.

13A Process Equipment. Units made from Karbate impervious graphite & utilizing proven designs offer long life & low maintenance. National Carbon Co.

14L Heat Transfer Equipment. Built from Ampco 8 or one of the other alloys available units will do specific job with minimum maintenance. Downingtown Iron Works, Inc.

15A Valves. A chemical porcelain-to-porcelain seal in Lapp valves provides maximum chemical resistance. Standard on all Y & angle valves. Lapp Insulator Co., Inc.

16A Valves. Cast iron valves which stay tight even on soap oils & fatty acids. Ni-Rest bodies provide extra erosion-corrosion resistance. Crane Co.

17A Nitric Acid Plants. Combined know-how of Dupont & Girdler results in nitric acid facilities at lower investment & operating costs. Girdler Co.

18L Turbine Pumps. Verti-Line pumps said to contain every major improvement in this type all pioneered by Layne & Bowler Pump Co.

19A Stainless Steel Tubing. For selection of the proper grade of stainless steel tubing for your needs contact Mr. Tubes at Babcock & Wilcox Co.

20A GLC Anodes. Sturdy performance of these anodes in electrolytic cell operations explains why major chlor-alkali producers rely on them. Great Lakes Carbon Corp.

21A Heat Transfer. Modern process heating employs Dowtherm an ideal transfer medium for high temperature, low pressure heat. Dow Chemical Co.

22A Pumps. Assured features of these pumps are long, trouble-free service life & low cost. For use in handling a large variety of materials. Aldrich Pump Co.

23A Air Preheaters. Increased heat transfer rates assure more throughput. Ljungstrom air preheater saves 20% fuel costs. Air Preheater Corp.

24L Condensers. Because trouble has been engineered out Conseco units offer maximum operating efficiency. Ask for bulletins Condenser Service & Engineering Co., Inc.

25A Diaphragm Valves. To get complete facts on K & M diaphragm control valves ask for new data catalog. Also the valve size slide rule calculator. Kieley & Mueller, Inc.

26A Ion Exchange Systems. Every major component of a Permutit water-conditioning or ion exchange system is built by the Permutit Co. to assure specific job being done properly.

27A Piping. Eight basic types of corrosion resistant & plastic tube & piping, plus fittings, etc. for protected chemical systems. American Hard Rubber Co.

28A Chemical Plant. Another vinyl acetate plant to be built by The Lummus Co. design engineers & constructors for petroleum & chemical industries.

30A Controlled Volume Pumping. The Pulsafeeder provides dependable precision pumping. Elimination of stuffing box resolves maintenance problems. Lapp Insulator Co.

32A Petrochemical Plants. Chemical manufacturers who now produce petrochemicals will find it advantageous to contact M. W. Kellogg Co. on engineering problems.

37A Sulfuric Acid Plants. Over 6 million tons of sulfuric acid are produced in Chemical Construction Corp. designed & constructed plants.

39A Process Equipment. Individualized chemical equipment fabricated from variety of materials which meet ASME codes is specialty of L. O. Koven & Bro., Inc.

41A Continuous Infrared Analyzers. Former Phillips instruments now available—continuously reveal analysis of process stream contents. Cons. Engrg. Corp.

42A Utility Support. Called Lab-Jack unit is made of aluminum & stainless steel with plastic control knob. Quickly adjustable. Central Scientific Co.

43A Filters. If yours is a filtration problem complete engineering, design, & laboratory facilities are available without cost from Dollinger Corp.

44L Plate Filters. Versatile adaptability for all types of filtering provided in the Sparkler horizontal plate filter. Sparkler Mfg. Co.

45A Mixing. If you have a problem in handling high consistency materials Bethlehem Foundry & Machine Co. may be able to work out a solution.

46L Heat Exchangers. Aerofin type B smooth fin heat exchangers eliminate air resistance & turbulence of old type coils increasing fins per inch used. Aerofin Corp.

47A Process Plants. Every phase of processing from plant construction to unit design & process evaluations efficiently handled. by Badger Mfg. Co.

48A Fertilizer Plants. If it is a phosphate fertilizer plant that you want to build, consult Fluor Corp., Ltd., specialists in the field.

53A Heat Exchangers. Standard units in many sizes & types of shell & tube arrangements available from stock. Also build

DEVELOPMENTS OF THE MONTH *(Cont.)*

70 Need low-cost, portable apparatus for analysis of gaseous mixtures, low boiling liquids? Perkin-Elmer, Norwalk, Conn., has new Vapor Fractometer to do the job, based on the principle of gas chromatography. Method also used for separation of unknown components which are then analyzed by infra-red or mass spectroscopy. Analysis time: ½ to 5 minutes. Reproducibility: better than ½%. Sampling techniques, according to Perkin-Elmer, are simple, as are calculation procedures. Complex mixtures can be handled. Additional details can be had by encircling number 70 on Data post card.

(Continued on page 52)

units for special purposes. Patterson-Kelley Co., Inc.

55A Insulation. J-M 85% magnesia is lightweight, easy to install. For temperatures to 600° F. Ask for information. Johns-Manville.

57A Process Equipment. Whether your need is a pressure vessel or a storage tank consult Chicago Bridge & Iron Co. longtime specialists in the field.

59R Process Equipment. Engineers are ready to design & fabricate the unit you require be it kettle, reboiler, or reactor upon application to Manning & Lewis.

61R Research Laboratories. Are you going to build a research laboratory? Wigton-Abbott Corp. can serve you from design to operation.

62L Drying Agent. Called Florite this economical granular drying agent successfully treats a large variety of substances. Floridin Co.

63R External Bearing Pump. Unique design, wide selection of body block & liner materials, capacities 5 gal./min. with 0 to 50 lb./sq.in. discharge pressures feature the X-B pump. Vanton Pump & Equipment Corp.

64L Filter Materials. Filter papers for every use both regular & special grades are the product of Eaton-Dikeman Co. exclusively engaged in their manufacture.

64BR. Mixers. A portable mixer in sizes 1/20 to 7½ H.P. makes small batch mixing economical. Easy to attach to any open container. Alsop Engineering Corp.

65R Dryers. Tunnel Truck dryers from Proctor & Schwartz Inc. now feature new housing construction offering added advantages.

66TL Vacuum Problems. Use of the I-R steam-jet ejector said to solve many vacuum problems by utilizing steam otherwise wasted. Ingersoll-Rand.

66B Plug Valves. Aluminum body plug valves with faces of special corrosive resistant rubber compound are often key factors in processing systems. DeZurik Shower Co.

67R Process Engineers. Engineers, designers, fabricators of process plants & equipment are available to you from Industrial Process Engineers.

68L Defoamer. The space now wasted on foam can increase your output 100%. Two types of silicone defoamers both physiologically harmless. Dow Corning Corp.

Numbers without letters indicate data available as described in Data Service "Briefs." Numbers with letters refer to further data concerning products advertised in this issue. Letters indicate position of advertisement on page (if more than one on a page)—L, left; R, right; T, top; B, bottom; A indicates full page; IFC, IBC, and OBC are cover advertisements.

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IFC	3R	4-5A	6L	7A	8A	9A	10L	11A
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21A	22A	23A	24L	25A	26A	27A	28A	30A
32A	342A	37A	39A	41A	43A	44L	45A	46L
47A	48A	53A	55A	57A	59R	61R	62L	63R
64L	64BR	65R	66TL	66B	67R	68L	68R	69R
70TL	70BL	71R	72L	72R	73R	74L	76TL	76BL
77R	78L	79R	81TR	81BR	82TL	82BL	83R	84L
84TR	84BR	85TR	85BR	90L	90TR	90BR	91TR	91BR
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47A	48A	53A	55A	57A	59R	61R	62L	63R
64L	64BR	65R	66TL	66B	67R	68L	68R	69R
70TL	70BL	71R	72L	72R	73R	74L	76TL	76BL
77R	78L	79R	81TR	81BR	82TL	82BL	83R	84L
84TR	84BR	85TR	85BR	90L	90TR	90BR	91TR	91BR
IBC	OBC							

Chemical Engineering Progress Data Service

Name .....

Position .....

Company .....

Address .....

City .....Zone.....State .....

☐ I want a subscription. Bill me $6.00 for a year.

August, 1955

products-(Cont.)

68R Power Transmission Equipment. Economical, easily installed, maintenance free flexible couplings, speed pulleys, etc. in all types & sizes for all applications. Lovejoy Flexible Coupling Co.

69R Evapora ive Heat Exchanger & Quench Bath Cooler. Accurate temperature control of hydraulic liquids prevents losses. Other Niagara machines cool water, oil, other solutions. Niagara Blower Co.

70TL C• lers. Use of Trufin tube gives increased area & performance in same size shell. Unit fabricated from stainless steel. Richard M. Armstrong Co.

70BL Blenders. Accurate blending of two or more liquids in preset proportions, automatically accomplished in closed continuous production. Bowser, Inc.

71R Castings. Heat, corrosion, & abrasion resistant castings made of Duraloy or Duraspun are carefully controlled & quality tested. Duraloy Co.

72L Double Cone Blender. Review all the features of Gemco double cone blenders & in addition write for complete information. General Machine Co. of New Jersey.

72R Comparators. You can test pH chlorine on the spot with these comparators. Line of color standards guaranteed. W. A. Taylor and Co.

73R Oxygen Analyzer. The well-known F3 unit now built with meter on the door. Free literature describes operating principle. Arnold O. Beckman, Inc.

74L Funnels. Made of Pyrex glass a wide range of capacities & varied features available in separatory funnels from stock. Ace Glass Inc.

76TL PVC Pipe. Injection molded fittings on PVC pipe last & last. Handle corrosive materials at pressures to 100 lb./sq.in. Tube Turns Plastics, Inc.

76BL Adjustable Sprocket Rim. Every valve becomes easily accessible when using this redesigned adjustable sprocket rim. Easier, quicker, more solid assembly result. Babbitt Steam Specialty Co.

77R Heat Exchangers. If you need heat exchangers check with Paracoil & profit in experience, quality, economy & delivery. Davis Engineering Corp.

78L Process Equipment. Design, development, fabrication of tanks, piping, etc. as well as special equipment from corrosion resistant alloys available from Misco Fabricators, Inc.

79R Exposition of Chemical Industries. All chemists & chemical engineers will be interested in the 25th Exposition in Philadelphia. Chemical Industries Exposition.

81TR Process Equipment. All types of storage & process stainless steel tanks, also agitators available. Write for literature. Arthur Colton Co.

81BR Rotary Dryer. Called DehydrO-Mat unit dries all chemicals quickly & economically. Information on request. Edw. Renneburg & Sons Co.

82TL Mixer. Extremely good agitation & mixing without entrapping air is claim for Hermas jet mixer. Hermas Machine Co.

82BL Nozzles. Full or hollow cone, also spray and other types of nozzles listed in comprehensive catalog from Spray Engineering Co.

83R Storage Tank. Called Pla-Tank unit was used for storing 20% sodium hypochlorite bleach solution. Built from resin-bonded glass fiber laminate. Pla-Tank, Inc.

84L Ion Exchange. Using water as a regenerant iron removal is accomplished by anion exchange in equipment from Illinois Water Treatment Co.

84TR Technical Data Books. Printed on pocket size loose-leaf sheets books contain 140 pages of technical data on variety of subjects. Lefax Publishers.

84BR Scientific Research. A service which saves you both time & money when you want scientific research without capital investment. Foster D. Snell, Inc.

85TR Pumps. For abusive service in handling abrasive or corrosive materials or hot liquids pumps which rule out leakage, failures & packing troubles. Nagle Pumps, Inc.

85BR Process Piping. Tubing fabricated from a complete range of alloys any shape & diameter to 60 in. Wall thicknesses ⅜ in. Pressed Steel Co.

90L Process Equipment. Permanite a furfuryl alcohol resin reinforced chemical fibreglass used to construct corrosion proof pipes, fume ducts, towers & tanks. Maurice A. Knight.

90TR Arched Wafers. A new process & a new service. Arched wafers of your product. Said to have advantages over other shapes. Flakice Corp.

90BR Precipitator. Konisampler used for continuous, accurate dust sampling & for permanent records. A light weight, quiet, all electric automatic timer. Joseph B. Ficklen, III.

91TR Grinders. Large scale production mills for use on variety of materials ground to 10 to 100 mesh, some as fine as 200 mesh. Gruendler Crusher & Pulverizer Co.

91BR Cooling Equipment. Chill-Vactor a product of Croll-Reynolds Co., Inc. only one type of steam-jet evactor in their line. Technical staff available for aid on vacuum problems.

342A Materials Recovery. Increasing absorbable component recovery without increasing height of packed column described in ad. Ask for free booklet. United States Stoneware Co.

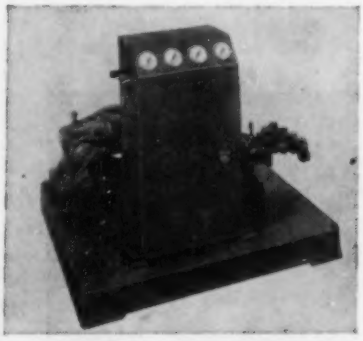
IBC Fintubes. Better design means better performance. Brown's design eliminates baffles. Brown Fintube Co.

OBC Mixers. How Lightnin mixers meet shaft whip detailed. See list of literature for the asking. Mixing Equipment Co.

DEVELOPMENTS OF THE MONTH (Cont.)

67 Controlled volume pump with instrument air stroke length adjustment. Provides automatic control of pump capacity by air signal from remote pneumatic controller. Milton Roy Co. Philadelphia, Pa., manufacturer of the new motor driven pump, has designed the pump with a plunger stroke length that is infinitely variable from 0 to 100% of full stroke according to standard 3-15 lbs./sq.in. instrument control air output. When equipped with a pneumatically variable speed drive motor, the pump allows capacity adjustment by two remote instrument control air signals, according to Roy. Thus, extremely close control over pump capacity, and process variables, can be effected. The instrument air stroke adjustment feature is available on all standard Roy simplex controlled volume pumps using motor drives up through 7½ hp. For every pound or fractional pound of instrument air loading there is a definite plunger stroke length.

Reverse operation can be effected by simply changing the linkage in the pneumatic controller. High accuracy is maintained, says Roy, since the pump does not make use of lost motion linkage. The unique design and instrument air stroke



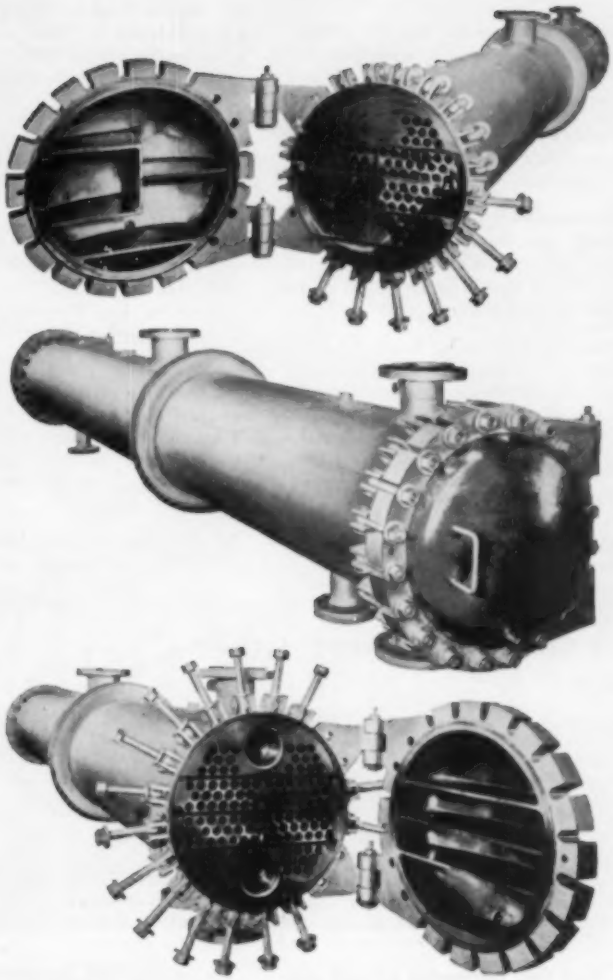
positioning, fully covered by patent application, leaves no unbalanced vertical thrust components. Further information by circling number 67 on Data post card.

(Continued on page 54)

a juicy problem

Pasteurizing fruit and vegetable juice in continuous flow is another way **p-k** special purpose heat exchange equipment is being used.

All parts of this unit which are in contact with the juices being processed are of stainless steel construction. It opens at both ends for easy, clinical cleaning. Uses six tube-side juice passes for efficient heat transfer. Materials, design details and finish conform to ASME and the most rigid sanitary standards. Here is another typical example of **p-k** thermal engineering and mechanical design.



Will standard equipment meet your needs?

p-k has designed and built dependable special purpose heat exchangers for years. This engineering and fabricating experience works to your advantage when you ask **p-k** for ideas on heat exchange problems. Your process may require special equipment, but, on the other hand, standard **p-k** heat exchangers may be your answer. If you can use standard units, available in many sizes and types of shell and tube arrangements, you can save on delivery time and engineering costs.

First step is to write now for Catalog No. 12 which provides all essential engineering data on heat exchangers and other processing equipment.

1918

the **Patterson-Kelley Co.,** *Inc.*

1780 Lackawanna Ave., East Stroudsburg, Pa.

bulletins.

1. Control Instruments. Gotham indicating, recording, & controlling instruments by United States Gauge, illustrated & described in folder.

2. Portable Sampler. Konisampler unit produces dust specimens suitable for microscopic examination. Joseph B. Ficklen, III.

3. Electrothermal Tape. Knitted electric resistance tape for heating pipes, valves, gas cylinders. Can be stretched or squeezed to fit. Widths to 3½-in. lengths to 8 ft. Arhur S. LaPine & Co.

4. Screening Separators. Sweco Separator catalog from Southwestern Engineering Co. features photos, drawings, detailed specifications of equipment with application data on many of more than 241 different materials.

5. Porous Metal Filters. Sintered bronze filters catalog from Permanent Filter Corp. For filtration of liquids or gases at any temperature.

signed for use with liquids or gases for stop-start operations. Proper selection, coil construction, covered.

10. Porous Stone Air Filters. R. P. Adams Co. Poro-Stone air filters. Bulletin covers operation for removal from compressed gas any entrained oil, foreign bodies.

11. Plug Valve Lubricants. ACF Industries Inc. manual covers lubricants for ACF plug valves. Sections on forms & descriptions of lubricants, features lubrication, service recommendations.

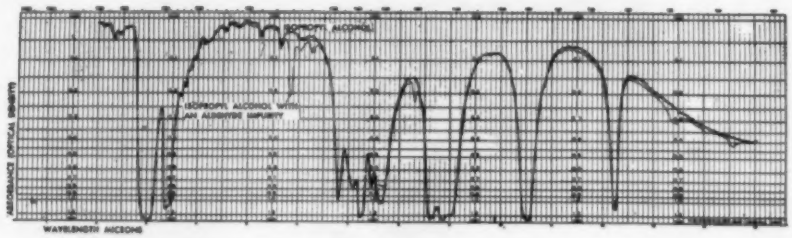
12. Portable Mixers. A portable mixer said to possess new features is described & illustrated in bulletin from International Engineering, Inc. Convertible from adjustable shaft type to non-adjustable in minutes.

14. Graphite Electrodes, etc. Synthetic graphite as a process material is covered in a bulletin from Electrode Div., Great Lakes Carbon Corp. Dependability, uniformity of product, engineered performance, other considerations.

15 Corrosion Resistant Valves. Monel & nickel corrosion resistant valves described

DEVELOPMENTS OF THE MONTH *(Cont.)*

CHEMICAL



83 Need fast, inexpensive infra-red spectroscopic analysis? Electrical Testing Laboratories, Inc., New York, offers complete facilities for this precise, reproducible analysis. All organic, and many inorganic compounds, regardless of their complexity, have a characteristic infrared absorption spectrum. Purity, presence of key materials or minor components can be determined qualitatively and quantitatively. In the above test, a small amount of aldehyde has been detected in a sample of isopropyl alcohol. The quantity is easily found by comparison with prepared samples at various known concentrations of aldehyde. Details of this service by encircling number 83 on Data post card.

(Continued on page 56)

6. Laboratory Glassware. Diamond D Blue Line includes all graduated items covered in current D54 catalog of Doerr Glass Co.

7. Recording & Control. Continuous indication, recording & control of viscosity under process conditions as accomplished by the Viscometran from Brookfield Engineering Labs., Inc. set forth in leaflet. Explain principle of operation, advantages, & give installation data.

8. Spectrographic Source Unit. Detailed information in Baird Assoc. bulletin on three circuits available in unit which enables operator to select optimum conditions for various analytical problems.

9. Solenoid Valves. A-P Controls Corp. bulletin covers line of solenoid valves de-

in Alloy Steel Products Co. bulletin. Describes applications, compositions, & mechanical properties.

17 Insulating Material. Gilsulate material may be poured on, tamped down, & backfilled. Provides high insulation value plus permanent corrosion protection for hot pipe lines. American Gilsonite Co.

18 Stress Rupture. Babcock & Wilcox Co. punched binder insert card chart on stress rupture values of stainless steel weld deposits. Guide for vessel designers.

19 Rotameters. An all-inclusive catalog from Brooks Rotameter Co. on full-view rotameters. Construction, safety features, dimension drawings, tube & float material design data given.

20 Control Equipment. Pressure, hydraulic, temperature, process & combustion controls in line of A. W. Cash Co. listed in illustrated bulletin.

21 Stainless Steel Data Book. From Cooper Alloy Corp. an engineering data book for use as part of their new catalog literature. Includes design & dimensional information on flange drilling, ratings & conversion factors, etc., plus materials selection chart covering over 300 corrosive solutions.

22 Minerals Flotation Cell. Bulletin from Denver Equipment Co. explains how Sub-A cell recovers coarse minerals, reduces losses in plant tailings, increases capacity of circuit and lowers power consumption.

23 Pressure Vessels. Guide to the types of process vessels fabricated from steel & a long list of alloys is subject of bulletin from Downingtown Iron Works, Inc. Engineering & estimating service available without obligation.

24 Standardized Control Instruments. Process control instruments for immediate shipment from stock located at strategic points are described & illustrated in Fischer & Porter's new catalog. Complete specifications are included.

25 Dehumidifiers. Available in a large range of sizes Oriad dryers from C. M. Kemp Mfg. Co. are used for drying air or gases used to actuate instruments, valves, etc. Complete descriptive information, specifications, dewpoint & selection charts included.

26 Temperature Control. Several types of pressure controls, one a two-stage remote stem control are fully detailed in new bulletins from Mercoid Corp.

27 Process Control. Binder insert bulletins 1130 from Minneapolis Honeywell devoted to application of process control in the process industries. Covers description & selection, types of program controllers for typical processes.

28 Centrifugal Mixer. Neumann & Weaver Inc. U. S. representatives for Rheinhuette bulletin on a centrifugal mixer. Unusual design of rotor achieves efficient circulation of even highly viscous liquids, slurries and pulpy suspensions. Specifications, test reports, schematic diagram included.

29 Thermal Recuperator. Furnace unit made under Fitch patents now fabricated & sold by Petrocarb Equipment, Inc. Gases to be heated drawn through tubes, with combustion gases around tubes. Same heat transfer tubular elements will be continued in use. Engineering service supplied. Special materials of construction available.

30 Cooling Towers. Specifically designed for air conditioning applications Lo Line cooling towers from J. F. Pritchard Co. Capacities of 75 tons & up includes many unique features. Bulletin available.

31 Industrial Meters. Accurate register type meters for suppliers of liquid propane or oxygen, anhydrous ammonia. Rockwell

(Continued on page 56)

J-M 85% Magnesia is lightweight . . . easy for workmen to install half-sections on this 10″ steam line. Insulation work at the Grace Chemical plant was performed by Young Sales Corporation of St. Louis. Engineering and construction was directed by Foster Wheeler Corporation of New York.

Your Btu's and dollars go further when you specify **Johns-Manville 85% Magnesia**

. . . the choice of insulation engineers at Grace Chemical's new Memphis plant

INDUSTRY'S LONG-TIME standard for temperatures to 600F is still your best insulation buy. For J-M 85% Magnesia provides high insulating value, easy application, long life, initial low cost and minimum maintenance. That's why insulation engineers consistently specify J-M 85% Magnesia for modern installations like Grace Chemical's new anhydrous ammonia-urea plant. That's why it will pay you to specify J-M 85% Magnesia for your new plant or modernization program.

To assure you maximum value from your insulation dollar, Johns-Manville gives you complete drawing-board-to-job-site service. You get expert recommendations by the world's most experienced insulation engineers . . . plus expert installation by authorized J-M Insulation Contractors. Write today for further information on J-M 85% Magnesia and Johns-Manville's unmatched facilities to solve your insulation problems. Address Johns-Manville Box 60, New York 16, N.Y. In Canada, Port Credit, Ontario.

J-M 85% Magnesia also comes in block form. Here you see it being applied to a vertical drum at a New Jersey petroleum refinery.

JM PRODUCTS

Johns-Manville *first in* INSULATION

MATERIALS · ENGINEERING · APPLICATION

bulletins-(Cont.)

Mfg. Co. bulletin explains & describes units, also Parkhill Wade dispensing system & its advantages for high vapor pressure liquids.

32 Controlled Volume Pumps. Model H-20 in the Milton Roy Co. line of pumps described in new bulletin. Information on duplex & simplex models, capacities, pressures, construction, etc.

33 Continuous Steel-Belt Conveyors. 48-page book gives extensive engineering & application information on Sandvik Stainless Steel Belt Conveyors. Suitable for solidifying molten sulfur and salts, chilling, and host of other applications. Book contains details of construction, properties of steel belts, other information.

34 Scrubbers. Complete technical details on fume scrubbers & packaged scrubbing systems available in new bulletin from Schutte and Koerting Co. System employs water or other suitable liquid as educting and scrubbing agent. May be adapted for handling solid or liquid particles or gases.

35 Totally-Enclosed & Explosion Proof Motors. New series of improved motors are subject of bulletin from U. S. Electrical Motors, Inc. Redesigned to smaller sized cast-iron cases for h.p. ratings.

36 Flow Transmitters. Several types of mercuryless transmitters from Hays Corp. Used in connection with measurement of liquid level, differential pressures, fluid, gas, air or steam flow. Illustrated bulletin. Features six counter continuous integration, 12 in. uniformly graduated charts & choice of indicators.

37 Solenoid Valves. A new catalog from Valcor Engineering Corp. includes drawings & specifications on the floating seal solenoid valve designs featuring model SV-2700. Also a sanitary valve with a see-through body, & new 2-way, 3-way & flow diverter valves.

40. Water Treatment Flow Diagrams. New, plastic-laminated, permanent flow diagrams are designed to increase operating convenience of Graver Water Conditioning Co. water treatment equipment.

41. Explosion-Proof Pump. Eco Engineering Co. unit for corrosive & hazardous materials. Positive displacement, of stainless steel with chemically inert mechanical seal. Flow rates to 10 gal./min. at 100 lb./sq.in./gage.

42. Packless Solenoid Valve. Direct lift for application to 7 lb./sq.in. max. pressure, in ⅜ & ½ in. pipe sizes. Automatic Switch Co.

43. Gas Pressure Regulator. Developed by Reaction Motors, Inc. new type unit provides dependable pressure control over wide range of temperatures & pressures. Design permits compact installation.

44. Inconel Sheathed Electric Heaters. Two new all-metal far-infrared electric heaters by Edwin L. Wiegand Co. One equipped with standard screw base; the other with bi-post terminals. Both may be used to replace infrared glass lamps. Resist vibration & shock.

45. Spray Nozzle. Developed by Spraying Systems Co. a hydraulic spray nozzle with remote compressed air actuated piston flow control permits spraying to be indexed to requirements of operations where intermittent spraying is needed.

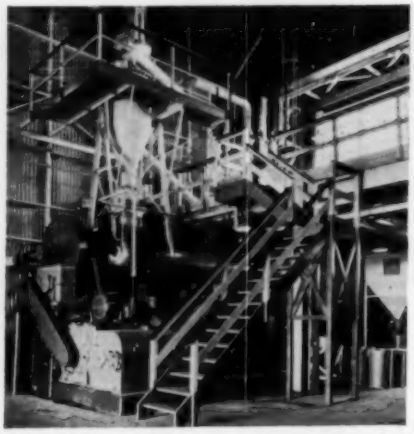
46. Lighting System. For use in hazardous processing areas—complete lighting system introduced by Crouse-Hinds Co.

47. Brine Reference Book. Book on the Lixite process "Brine for Today's Industry" published by International Salt Co. Replaces previous edition, contains more technical information.

48. Electric Oven. Batch type electric oven accepts truck loadings. Fully automatic, also available with gas heating system. Grieve-Hendry Co., Inc.

DEVELOPMENTS OF THE MONTH (Cont.)

84. New Dryer Boosts Terramycin Output. Faced with the problem of significant losses of highly valuable Terramycin during drying, Chas. Pfizer took a close look at the drying phase of the antibiotic's production. The company found the problem was not a single one. First, it was clear that forced air drying, in the case of Terramycin, caused loss of product and necessitated elaborate dust collection systems. Another method of drying would save product. But, and here was the second problem, the pharmaceutical industry is growing and changing so rapidly that the company had to make savings of product sufficient to justify the risk of early obsolescence of Terramycin itself. After considerable study, Pfizer decided to use a 5 × 30 foot stainless steel Buflovak Vacuum Rotary Drier manufactured by Buflovak Equipment Division, Blaw-Knox Company. Since installation, the drier has proven to be the answer, drying a batch in less than 10 hours rather than the expected time of 12 hours. In operation the unit is charged from the top, the 70% moisture filter cake tumbled at 2 r.p.m. by heated agitator blades. At no time does the temperature of the Terramycin exceed 80° F.



Further information on specific applications can be obtained by circling number 84 on Data post card.

(Continued on page 58)

equipment-

49 Pyrometers. Three sizes of sealed & ruggedized instruments added to line of Assembly Products Inc. Ten case styles available. All have automatic bimetal cold junction compensation & thermistors for high accuracy over wide variation of ambient temperature. Accuracy within 1%.

51 Spectrophotometer. Beckman Instruments Inc. new automatic infrared spectrophotometer for both research & quantitative analysis. Bulletin emphasizes performance giving full specifications & exact reproductions of transmittance type curves.

52 High Speed Recording Potentiometer. A recording wide-strip potentiometer with full-scale pen travel in 0.4 sec. available from Bristol Co. Efficient for recording of rapidly changing variables. Chart speeds to 4 in./sec. offered.

53 Magnetic Data Storage Device. Tape-DRUM device combines advantages of magnetic drum & tape recorder. Details in folder from Brush Electronics Co. Principal applications are inventory control, data reduction. Gives simultaneous recording from 128 digitized control points.

54 Liquid Cyclones. Centrifugal & Mechanical Industries, Inc. announce a series of liquid cyclones. Called Clust-R-Clone. Consist of small cones into which suspension is pumped. Designed to meet need of more efficient means of thickening, dewatering, classifying, separating, & deslimming liquid-solid mixtures. Illustrated folder gives further details.

55 Hydromatic Control Valve. Cochrane Corp. valve for use on ion exchange water softener & demineralizer equipment provides accurate control during regeneration. Design includes internal diaphragm operated valves faced with soft rubber insuring drop-tightness & non-scoring.

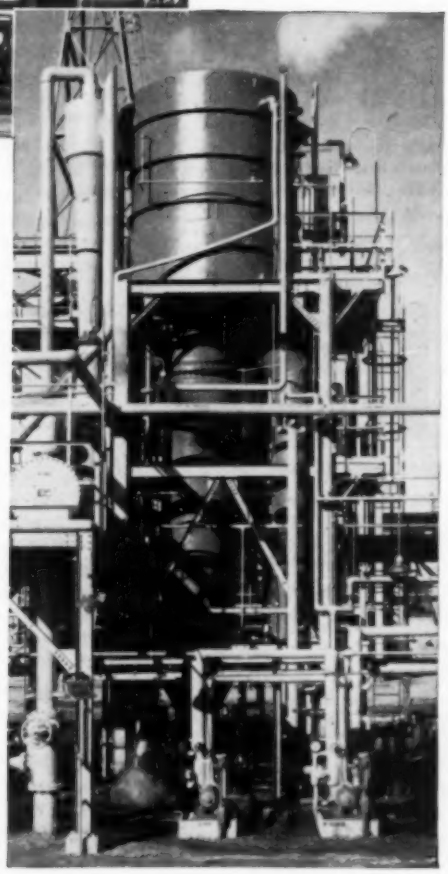
56 Check Well. Unit combines sensitive thermocouple with dial type thermometer for quick visual check of critical temperature points. High rate of response due to small 3/16 in. O.D. thermocouple protection tube with subsequent low mass, low thermal inertia & light gage thermocouple element with hot junction bottomed in tube. Conax Corp.

57 Current Controller. Booklet describes model EB current controller a unique pneumatic-electric transducer. Provides auto-

(Continued on page 58)

A Reactivator tower for Monoethanolamine...

or a Urea Concentrator...



...a pressure vessel or a storage tank... Chicago Bridge & Iron Company is building them throughout industry today. CB&I is a specialist... with strategically located plants staffed to design, engineer, fabricate and erect welded steel plate structures to meet the most exacting requirements. Our plants are equipped for stress relieving and X-raying and have facilities for pickling and painting fabricated material.

When planning welded plate structures of any sort, be sure to write Chicago Bridge & Iron Company's nearest office. They will provide information, estimates or quotations.

Top left: 10-ft. 6-in. diam. by 87-ft. 6-in. high monoethanolamine (MEA) reactivator, fabricated by CB&I for the Grand River Chemical Division of Deere and Company at Pryor, Oklahoma.

Lower left: Conkey single effect evaporator of the vertical tubular type, all stainless steel construction, for production of high concentration urea liquors for subsequent "Prilling".

CB&I

Chicago Bridge & Iron Company

Atlanta • Birmingham • Boston • Chicago • Cleveland • Detroit • Houston • Los Angeles • New York
Philadelphia • Pittsburgh • Salt Lake City • San Francisco • Seattle • Tulsa
Plants in BIRMINGHAM, CHICAGO, SALT LAKE CITY and GREENVILLE, PA.

equipment- (Cont.)

matic control of required current input in many industrial operations & processes. Illustrates typical examples of wide range applications possible.

58 Automatic Infrared Analyzers. Consolidate-Phillips automatic infrared analyzers now available from Consolidated Engineering Corp. Originally developed by Phillips Petroleum. Provides continuous analysis of specific components in gas streams. Continuous readings from stream being sampled can be telemetered for remote recording.

59 Magnetic Drum. Eriez Mfg. Co. permanent magnetic agitator drum for removal of small iron particles. Said to be unique in providing agitation for disentangling material being reclaimed. Available in 12 & 18 in. diam., widths from 10 to 38 in.

unloading of filter cake now built into Industrial Filter and Pump Mfg. Co. filters. Bulletin shows how leaves are easily removed for inspection & cleaning, lists features, shows cutaway view, gives much other information.

64 Stainless Steel Fittings. Designed for corrosion applications & introduced by Ladish Co. stainless steel Tri-Clamp fittings consist of a flange type ferrule & specially fabricated spring clamp which grips the ferrule edges, plus a simple, bolt-type coupler assembly secured to the clamp ring, always in position for instant assembly or disassembly. Bulletin.

65 Liquid Level Control. A displacement type single level stage liquid level control for high pressure service available from Magnetrol, Inc. Also useful in low pressure service. For operation with liquids having specific gravity of .40 or above. If required Magnetrols may be equipped with special purpose anti-vibration mercury switches.

DEVELOPMENTS OF THE MONTH (Cont.)

85 New fiberglass products for industrial maintenance. Owens-Corning Fiberglas Corp., Toledo, O., thinks so highly of its Fiberglas for maintenance, that it has a special trailer-truck touring the major plants of the nation to show its products. The truck body itself is Fiberglas, and displayed are: Kaylo block and pipe insulations, Fiberglas industrial insulations, roof insulations, Fiberglas-reinforced plastic panelling and pipe filters, electrical insulations, reinforced papers and tapes, baffles, and building materials. Two sales representatives travel with the trailer to give information. For further details circle number 85 on Data post card.

86 A new, corrosion-resistant Graphite Heat Exchanger which eliminates cemented joints and produces continuous turbulence is on the market. The "Polybloc" heat exchanger of Carbone Corp., Boonton, N. J., differs from other graphite units because the orientation of the graphite crystals gives higher thermal conductivity. Polybloc, according to Carbone, enables the user to install a smaller unit than would be required using ordinary graphite heat exchangers. For additional information circle number 86 on Data post card.

(Continued on page 60)

60 Steam Generators. An economy series of steam generating units developed by Foster Wheeler Corp. covered in brochure. Nine sizes with capacities 50,000 to 150,000 lb./hr. Working pressures to 1,500 lb./sq.in. without superheat; 1,100 lb./sq.in. with superheat. Oil or gas firing; choice of type & location of accessories.

61 Flow Control Regulating Valve. Hammel-Dahl Ultravalve is intended to be most economical and maintenance-free. Available in three styles. Internal parts removable through bonnet. Parts of three body styles are interchangeable. Teflon seal requires no lubrication or adjustment.

62 Positive Displacement Pump. Hills-McCanna new UMC pump for metering flow is actuated by solenoid operated single revolution clutch. Pump has served efficiently in automatic or timed proportioning of chemicals. Available in sanitary model for food industry. Capacities 10 to 20 gal./hr. feed.

63 Horizontal Pressure Filters. New features which speed operation & simplify

66 Filter. Millipore Filter Corp. offers new filter as a tool for the nuclear energy field. Two-color folder shows case histories using what is termed a revolutionary filter medium in monitoring laboratory exhaust ducts & reactor stack discharges to trap radioactive particles.

68 Tube Fitting. Intru-lok, flareless type tube fitting for copper instrumentation lines by Parker Appliance Co. Tube is inserted through nut & ferrule until it bottoms on seat within fitting body when nut is tightened. Wedging action causes ferrule to bite into outer surface of tube wall turning up a shoulder of metal to provide leakproof, vibration-proof connection.

69 Steam Generator. A 40 H.P. steam generator only 83 in. long, 57 in. high & 36 in. wide designed by National-U. S. Radiator Corp. Unit incorporates all late design improvements & safety devices for boiler protection to insure trouble-free operation & maintain 80% efficiency or better.

71 Mixer Drive. Pfaudler mixer drive engineered for use with a wide variety of materials. Several new features. Available for reactors to 100 gal. capacity. Speed is easily varied by manually adjustable sheaves to give agitator rotation from 60 to 300 rev./min. Gears rated to carry to 3.6 H.P. at 175 rev./min.

72 Gage Protector. An adjustable gage protector said to be of radically new design offered by Republic Mfg. Co. Has a spool-like plunger within a removable cartridge. Connections are in-line, & spring pressure adjustments or changes of cartridge are made without removal from line. Springs available at readings of 15 to 5,000 lb./sq.in. Body materials are aluminum & stainless steel.

73 Digital Totalizer. A totalizer that converts weight readings of a dial scale to digital equivalents announced by Richardson Scale Co. Remotely controlled, totalizer can be used with any industrial dial scale. Specially suited for control in receiving or shipping & processing material through an automatic hopper scale connected to the dial scale.

74 Hammer Mill. A new pulverizer, a vertical hammer mill with built-in classifier is new with Metals Disintegrating Co., Inc. Called MIKRO-Bud apparatus is unique in being able to shift from one particle size to another in grinding operations. Simple turn of knurled handwheel permits adjustment to run entire range of its particle sizing within 5 sec.

75 Propeller Fans. A line of belt-driven tubeaxial propeller fans designed for handling corrosive exhaust, high temperature, explosive fumes, & kindred operations. Five sizes 16 through 36 in. Delivery ratings to 26,000 cu.ft./min. Fan drum rolled from 12-gauge steel plate. Integrally rolled mounting flanges & continuous welded seam eliminate possibility of fume or condensate leakage & subsequent corrosion. Robbins & Myers, Inc.

76 Evaporator. A portable laboratory model Turba-Film evaporator for pilot plant study of unit operations of evaporation, single-step distillation, heat treatment available from Rodney Hunt Machine Co. Uses their agitated film method & is provided with heat transfer area of 1 sq.ft. Built of type 316 stainless steel throughout. For heating mediums to 250 lb./sq.in. gauge & 700° F.

77 Thermodynamic Steam Trap. Called type TD-50 unit is machined from stainless steel bar stock, & consists of body, cap, & a solid stainless disc which is only moving part. Operates efficiently on steam pressure from 10 to 600 lb./sq.in. & on light or heavy loads. Sarco Co., Inc.

78 PVC Pipe Fittings. A complete line of solvent welding pipe fittings & flanges of injection molded unplasticized polyvinyl chloride. Said to be a first on a commercial scale by the injection molding process. An addition to Tube Turn Plastics, Inc. line of threaded fittings. Both lines include 90° & 45° elbows, tees, unions, couplings, caps, bushings, & flanges.

(Continued on page 60)

Transfer of Jefferson Chemical's headquarters from New York to Houston, Texas, was made on July 1. This brings Jefferson's offices close to its plant at Port Neches, Texas, and research laboratory at Austin, Texas. □

A 25,000% increase in the demand for foamed plastics. That's the prediction of Nopco Chemical Co., Harrison, N. J., and on the basis of it Nopco is planning to establish a Plastics Division, spend $1 million for expansion.

Basing its prediction on a market analysis, Nopco already has plans for completion of two plants this year (capacity: two million pounds of both urethane and vinyl foams), a third next year. □

The beginning of operations of **new $4,000,000 DMT (dimethyl terephthalate)** facilities at Hercules Powder Company's Burlington, New Jersey, plant will up production of DMT by one million pounds per month. DMT is a basic chemical for the manufacture of 'Terylene,' a new synthetic fiber, which will be made in Canada by Canadian Industries (1954) Limited.

The new Burlington plant addition will supply a new $22,000,000 plant of CIL at Milhaven, Ontario. □

Acquisition of the recently terminated agricultural chemicals program of the Ethyl corporation has been made by Pittsburgh Coke & Chemical Company, Pittsburgh.

One of the many compounds in the program is a new fungicide, B-622, which was recently publicized and which will get extensive field testing this year. The complete program includes chemicals for use as insecticides, fungicides, herbicides, defoliants, and growth regulants. □

An increased supply of urea will be available to West Coast farmers as the result of a new urea plant Shell Chemical Corporation is planning to build at Ventura, California. The plant will be the first west of the Rockies. Construction will start shortly and the plant will be in operation by September, 1956.

The new plant will have a capacity of more than 100 tons a day, will secure its raw materials, ammonia and carbon dioxide, from the adjoining Shell ammonia plant at Ventura. The manufacturing process has been licensed from Montecatini and The M. W. Kellogg Company has been selected as the contractor. □

Quality Fabrication is our Business
Whether its a kettle, reboiler, reactor or other process equipment, Manning & Lewis engineers and craftsmen are ready to design and fabricate a unit, tailor-made to fit your particular process need, and priced to fit your budget.
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equipment- *(Cont.)*

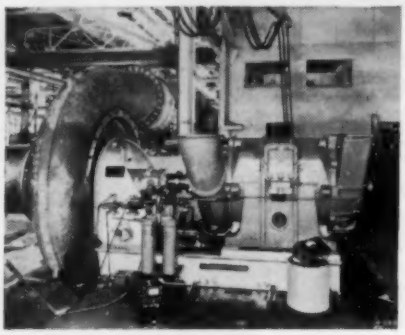
79 Dry Materials Feeder. Said to be a new, revolutionary chemical feeder which delivers consistently within 1% on most materials, minute to minute, or half minute to half minutes. Basic principle is a feed screw so mounted on a vibrator as to allow application of unlimited vibration to entire assembly. Insures complete filling of screw at all times, & emptying as well. Leaflet available from Vibra Screw.

80 Hour Indicator. Announced by Haydon Mfg. Co. a Running Time Meter indicating hours-of-operation to 10,000 hrs. on dial-type face. Weighs less than 6 oz. & has power drain of about 2 watts. Hermetically sealed according to AER specification & said to meet military shock (25 g) & vibration requirements.

81 2200° F Dynamic Pressure Pickup. For use of rocket & engine manufacturers as well as chemical & processing industries a pickup which operates under temperatures to 2,200° F. Designed by Endevco Corp. Features are in the cooling passage design, flat frequency response from 2 cps, to 5,000 cps. & output of 40 mv./lb./sq.in. in the 0 to 500 lb./sq.in. pressure range. Available in ranges of 500 to 5,000 lb./sq.in.

82 Relief Valve. An addition to line of Crosby Steam Gage & Valve Co. is the Protecto-Seal bellows relief valve. Designed for use on services where protection against corrosion, fouling of working parts, & low back pressure surges is required. Several exclusive features incorporated.

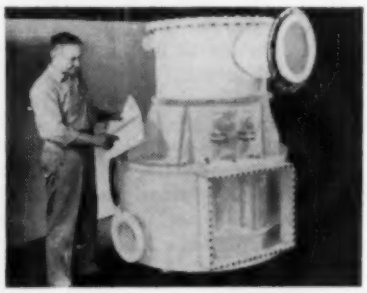
DEVELOPMENTS OF THE MONTH *(Cont.)*



87 An outdoor 43,200 cfm American Blower centrifugal compressor, direct-coupled to an ACEC 1250 hp., 3600 rpm electric motor, is being installed in the Petrofina refinery now under construction at Pointe Aux Trembles, Quebec. The compressor will serve as combination air lift and combustion blower. Operating on 3-phase 60-cycle current at 4160 volts, the ACEC motor that drives the compressor is a 2-pole squirrel-cage induction unit, cooled by forced ventilation and lubricated by a pressure-feed system. Constructed of forged steel to withstand strong centrifugal stresses, the rotor is statically and dynamically balanced for vibration-free rotation at high speeds. Because of the outdoor location, the motor is equipped with special heating facilities to prevent moisture condensation during cold-weather shutdowns. For further information circle number 87 on Data post card.

88 Do you want certainty in critical filtration? If so, Pall Filtration Companies, Glen Cove, New York, say they have the answer—glass bead filter calibration service on a fee basis. Pall's method is said to be very sensitive—as low as 0.0001% of beads passing is readily detected. Range of sensitivity: 5 to 80 microns. If sufficient demand exists extension down to one micron is planned. For details encircle number 88 on Data post card.

89 Having trouble handling hydrofluoric acid under 60% concentrations? Particularly in choosing a scrubber? Here is unit made of polyethylene—the largest scrubber ever made from this material. Manufactured by the American Agile Corporation, Maple Heights (Cleveland), Ohio, for a large chemical processor, this model measures four feet in diameter, five feet high, with a gas flow of 2500 cfm at 1½ lbs./sq.in. It will be used in contact with hydrofluoric acid and fluorides. Advantages of polyethylene for such equipment: Excellent impact strength and unbreakability, desirable low temperature properties, excellent chemical resistance at temperatures up to 170° F. Ducting, piping, valves, centrifugal fans, and tower packing are also available in self supporting fabrications made of polyethylene, and may be easily installed using the hot gas welding process. Additional information may be obtained by encircling number 89 on the Data post card.



materials-

85 Activated Carbon. A technical bulletin from Barnebey-Cheney Co. covers selection of proper grades & types of activated carbon for industrial processes, characteristics of their Adsorbite activated carbon & application of activated carbon processes in industry.

86 Flocculating Agents. Aerofloc reagents which accelerate settling & filtration have been developed by American Cyanamid Co. These large complex molecules when added to aqueous suspensions, bond together the individual fine solid particles in flocs. Bulletin.

87 Plasticizer. Diamond Alkali announces low-viscosity secondary plasticizer for polyvinyl chloride resins. Called Chlorowax LV, material is modified liquid chlorinated hydrocarbon providing viscosity lower than normal 40% chlorinated paraffins.

88 Gums. Two new commercially available base-polymers or gums for silicone rubber stocks from Dow Corning Corp. Data sheets cover all pertinent details.

89 Butyrate. From Eastman Chemical Products Inc. comes workbook containing latest information on formulation & use of half-second butyrate. Available to those who formulate & sell lacquers.

90 Plasticizer. Esterflex B-1 is a general purpose primary plasticizer for polyvinyl chlorides. Is first in series to be produced by Swift & Co. Results of use on finished products show good physical properties.

91 Vinyl Resins. Materials & methods for stabilizing vinyl resins are described in a technical bulletin from Witco Chemical Co. Booklet states there is presently no universal stabilizer for vinyl resins & analyzes factors which enter into individual stabilizing problems.

92 Flocculating Agent. Good-rite K-720 from B. F. Goodrich Chemical Co. is announced as a new synthetic resin flocculating agent for use in disposal or recovery operations involving clarification, sedimentation, or filtration.

93 Phosphorous Pentasulfide. Monsanto's distilled phosphorus pentasulfide made with pure electric furnace phosphorus is being marketed as a greenish yellow granular powder used by manufacturers of tiophosphates for oil & grease additives, ore flotation agents, etc.

94 Itaconic Acid Esters. Data sheet on this material offered by Chas. Pfizer & Co., Inc. Two esters are derived from itaconic acid, an organic compound made in commercial volume by fermentation. Used as intermediates & as monomers in preparing plastics. Detailed information available.

95 Furfural. New booklet from Quaker Oats Co. is devoted to physical data on furfural. Solubility of various chemicals & resins in furfural are tabulated.

96 Protective Coatings. A 19-page report on "Comparative Properties of Protective Coatings" available from Atlas Mineral Products Co. Gives information on 14 types of coatings for protection of equipment, walls, beams, & ceilings in plants where fumes & industrial atmospheres cause corrosion.

Engineers designing for the higher processing temperatures now being widely used, may have a new material to use where ordinary steel doesn't work without the need to jump to alloys with large percentages of expensive elements.

Work at Battelle Memorial Institute, sponsored by Alloy Casting Institute, on 21% chromium-10% nickel heat resistant casting alloy shows great promise for process equipment use.

The new alloy, designated as HF grade, appears to substitute effectively for alloys containing substantially greater amounts of nickel and chromium in the temperature range 1200° to 1600° F. As much as 20% nickel can be saved per casting. At 1400° F. the load carrying ability, according to tests, of the HF alloy is 14,000-15,000 pounds per square inch for 100-hour rupture life. This is about equivalent to the higher alloyed types. □

Use of precast concrete roof slabs throughout Hooker Electrochemical's Montague, Mich., plant, points up reasons for growing use of this method of construction in chemical industry. Hooker chose precast over poured concrete primarily for cost savings, ease of installation, reduced maintenance, reduced insurance cost, and fire resistance.

Stress relieving, 75 feet long, new gas fired furnace now in operation at Delta Tank Manufacturing Co., Baton Rouge, La., is one of the largest in the South.

Designed to produce higher quality pressure vessels and a wider range of products for the process industries, the new furnace, heated to 1300° F. by a series of gas jets, will accommodate, in single heats, vessels of 13 feet 6 inches in diameter, and 72 feet 6 inches in length. Lengths above the 72-foot capacity are readily handled by multiple or sectional heatings. □

Increasing demand from the plastics industry has caused the doubling of production capacity of *adp* pigment dispersions manufactured by the Acheson Dispersed Pigments (Texas) Co. □

Development Center — Nitrogen Division
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INSTRUMENTATION . . . TREATMENT . . . DISPOSAL OF INDUSTRIAL WASTE

Led by the Northern California Section, West Coast A.I.Ch.E. put in a busy day with the rapidly growing problem of industrial waste disposal.

From the day-long discussion of waste disposal problems, one of the most important facts emerging was the necessity of rigid control through instrumentation, particularly in continuous systems. A satisfactory treating system cannot be designed without reliable information on hand as to the variables encountered emphasized W. N. Greer, Leeds & Northrup. Since concentrations of contaminants can change rapidly in most industrial wastes, it is important to obtain data on a continuous basis.

There are many variables that must be measured and controlled through proper instrumentation in any industrial waste treating system. A major one is flow, and in some plants it is impossible to install any well-known measuring device, necessitating special measures such as feeding a salt solution into the waste stream and measuring by electrolytic conductivity. Other important variables that must be measured and controlled are pH, reagent requirements, changes in contaminant concentration, and load conditions.

Finally, waste treatment instrumentation should not require excessive maintenance.

Radioactive Wastes

A growing waste disposal problem is that involving radioactive materials. D. McDonald, of General Electric's Hanford Atomic Products Operation, Richland, Wash., discussing the problem in general, showed that while methods of radioactive waste disposal are available and effective, they are highly costly, particularly in chemical processing plants which recover plutonium and uranium.

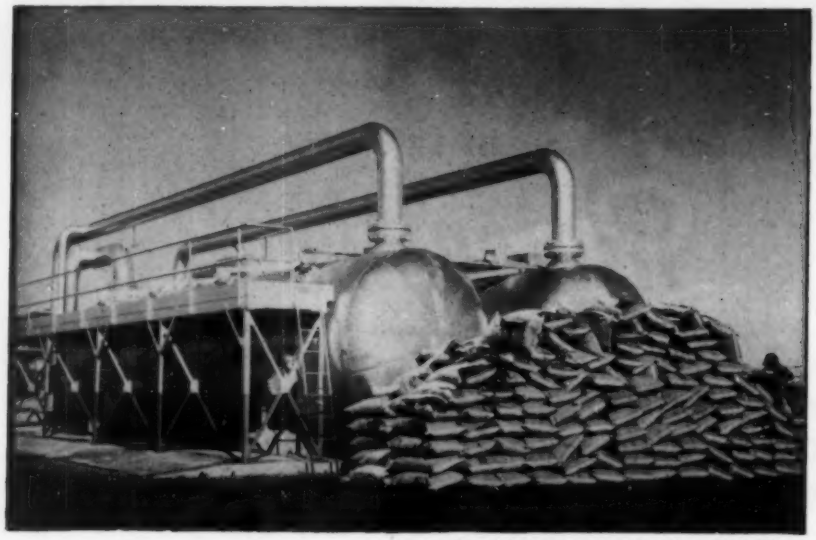
Because of the great danger, particularly in handling plutonium, the disposal and control measures at Hanford have been strict and efficient, but the cost is enormous. For example, no way has been found to effectively decontaminate equipment inexpensively. Burning is not effective, spreads the radioactivity, leaving the only solution the practice of burying in the earth, no matter how large the equipment may be.

The key is to make it possible to put large quantities of low radioactive level, or short half-life, wastes into the ground. All other methods are high cost. But this is not always possible, resulting in the excessive expense of waste disposal at atomic installations. Basically, the real solution is to develop methods to recover radioactive materials from the waste, rather than discard them and entail the problem of decontaminating them.

Refinery Waste

In handling refinery wastes, T. A. Dungan, Bechtel Corp., pointed out, as in any waste disposal problem, a major step is designing safeguards right into the blueprint of the plant. To make this practical it is necessary that the official body in charge of pollution in the area have definite specifications geared to the practical nature of the company's operation. Too many commissions have vague, unspecific, rules and regulations that leave the company unsure of just what it can and can't do.

Citing a recently-built Pacific Northwest plant, Dungan listed the following as typical refinery waste disposal methods: Segregation of sewers according to pollutants; removal of H_2S by stream stripping; gravity oil separation; chemi-



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cal flocculation; and biological oxidation of phenols.

Turning to more specific methodology, A. A. Kalinske, INFILCO, Inc., Tucson, Ariz., discussed the basic principles of liquid-solid and liquid-liquid separations involved in waste water treatment. Kalinske described and analyzed the function of equipment actually used to effect the separations. Here the meeting took up gravity separation and skimming, air flotation, chemical coagulation and settling, diatomaceous earth filtration, and many other methods.

An Applied Science

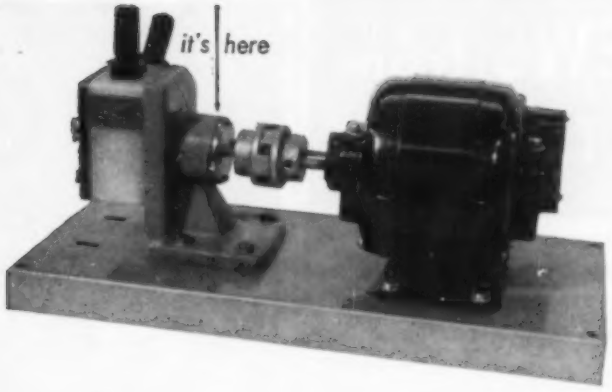
Since sanitary engineering is an applied science, developing rapidly in a short time and on an empirical basis to meet the problems in practice rather than theory, only recently has much work been done on understanding the chemical reactions involved. J. F. Thomas and E. S. Crosby, University of California, speaking on the subject of the chemical reactions involved in biological waste treatment, showed that, basically, biological waste treatment is concerned with the biochemical activities of bacteria. A complete understanding of the chemical reactions involved would explain the phenomena of self-purification of waters receiving organic wastes, but the knowledge is still very meager.

The interesting experimental use of polystyrene packing media in trickling filters and cooling towers was outlined by L. E. Tallman, Dow Chemical. The polystyrene has proven applicable as a medium for attachment of biologically active slimes. Advantages over conventional packing media—low unit weight and high ratio of void space to total volume occupied, high surface area to volume ratio, excellent free-vent characteristics, ease of assembly and packing, uniformity of material, availability, and flexibility in design of unit.

Air, Too

Drawing a strong parallel between air and water waste disposal problems, W. L. Faith, Air Pollution Foundation Los Angeles, showed the similarity of prevention techniques, indicated that air pollution can be a greater menace since there is no practical way to separate the air we breathe from the air we use as a "sewer."

The only answer in the long run is the same for stream as for air pollution —treatment of the waste and elimination of waste altogether rather than purification of already contaminated air or water. It is here, in the field of prevention and elimination of harmful wastes that the chemical engineer can make his major contribution.



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NEWS from FILTERTOWN

A recent survey establishes that clarity of filtration is the most important factor in the selection of a filter medium. Since E&D filter papers give the "finest" filtration, more E&D filter papers are used by industry than the total of all other filter papers combined . . . To cite but a few applications: grades 609 (WINE-BRITE) and 902 (*BREW-BRITE ®) are widely used in filtration of alcoholic beverages; 623 is extensively used for filtration of chemicals; 615 and 617 for foods and beverages; 613 for drugs and toilet preparations; and there are many more . . . This is not to say that any grade is universally used in any specific industry. Too many varying factors make this impossible. That is why E&D 's know-how, based on the practical experience of many decades, enables us to help you select the right grade for your particular assignment . . . Moreover, this is the only company in America exclusively engaged in the manufacture of filter paper for science and industry. There are many regular grades and special grades available. You can rely on any E&D filter paper to perform as recommended. Why take a chance on unidentified papers? The cost in loss of time and money can be serious . . . Write for free samples. Test them. Discover why E&D filter papers are used exclusively by most of America's leading industries . . . If you have a bothersome filtration problem write for our free Filtration Analysis Report. Chances are we know the answer . . . Used alone, or with cloth, there's an E&D filter paper to give you clarity of filtration and savings in time, labor and money.

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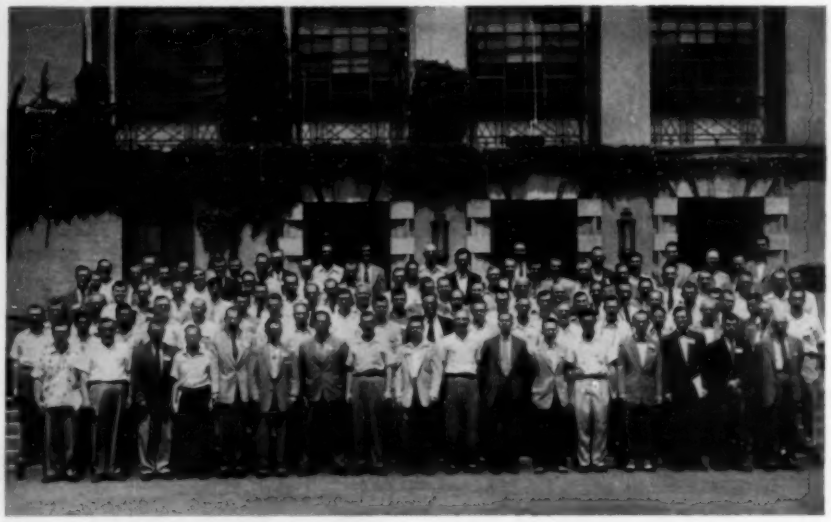

CHEMICAL ENGINEERING EDUCATORS GO TO SUMMER SCHOOL

Chemical engineering never stands still, and education for chemical engineering cannot stand still either. This basic fact brought 172 engineers and engineering educators to the Fourth Summer School for Chemical Engineering Teachers at Pennsylvania State University. So much was discussed only some high spots can be hit.

Perhaps the keynote of the week-long meeting was K. A. Kobe's comprehensive survey of current undergraduate curricula in chemical engineering. It is vital that the educator know what others are doing, and Kobe presented his detailed report for that very purpose.

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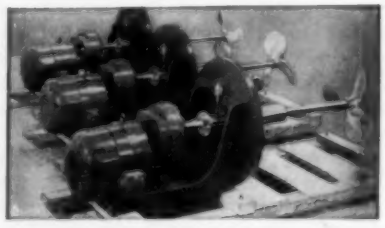

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Another high spot was nuclear engineering. The many papers on this subject attracted great interest, evoked much discussion. In general, the educators agreed with W. Kerr, Univ. of Michigan, that nuclear engineering subjects belonged at the graduate level. It was considered necessary that the student have a scientific background at least equivalent to a bachelors degree in engineering before tackling the nuclear field. G. H. Beyer, giving a talk on a Course On Nuclear Fuels and Wastes, proposed the idea that nuclear engineering be approached with a question: What can the chemical engineering educator, and the chemical engineer, contribute to the education of men interested in atomic energy? As examples of some things they can contribute, Beyer pointed to separations technology, distillation, ion exchange, and solvent extraction.

Kerr's talk, covering Nuclear Engineering Instrumentation, formed something of a bridge to another important segment of the talks, those on instrumentation and even automation. This subject, much in the engineer's mind lately, covers process control problems, computers, automatic and semi-automatic plants. More and more industry is turning to instrumentation, and the educator must follow suit.

Basic Subjects

With so much in the program, basic subjects were prominent in all aspects. Many papers covered mathematics, design and economics, process rates, unit operations teaching, thermodynamics and its instruction, and so on. But perhaps the most interesting of all the subjects discussed was the new concept of the Enginering Science Approach in chemical engineering instruction.

Many educators and educational institutions are looking carefully at this new concept, which, in essence, seeks to teach chemical engineering through the basic, fundamental concepts underlying all specific operations.

Prominent in this group of papers was the paper of Michigan University's S. W. Churchill. Dealing with graduate instruction in chemical kinetics and other rate operations, Churchill's paper clearly showed the path of integration by basic theory. Stating that with chemical engineering expanding so rapidly it is not possible or desirable to teach every aspect of technology, Churchill advanced the idea that the broad scientific perspective must be gained even at the expense of sacrificing instruction in the technology.

Basically, the summer school brought the educators together, let them compare problems and solutions, learn what is being done where and why.

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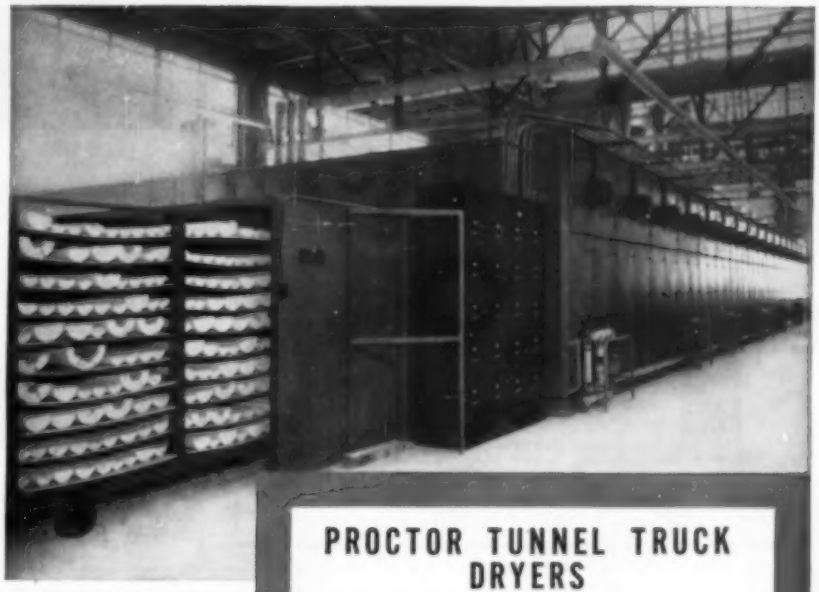

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ADDITIONAL CANDIDATES FOR 1956

The following pictures and brief biographies refer to candidates for director of the A.I.Ch.E. nominated by petition, and received by the Editor too late for inclusion in the July issue of C.E.P.

Raymond L. Copson

Director of research, Mutual Chemical Company of America, Baltimore, Md. Dr. Copson taught chemical engineering at Yale, from which he went to Socony-Vacuum, T.V.A., and Rumford Chemical before joining Mutual. He was chairman of Subcommittee on Student Contest Problem in 1936, and since then has been a member of the Education Projects, Publications, Program and Awards Committees, chairman of the Maryland Section, 1951-53.

Wheaton W. Kraft

Vice president and technical director of The Lummus Company, New York. Joined Lummus in 1929, following his training in chemical engineering at M.I.T. Became chief process engineer in 1935. Has lectured at Columbia and Brooklyn Poly. Has been technical program chairman of several Institute National meeting symposia. A specialist in chemical engineering operations, Mr. Kraft is an executive of one of the world's largest process engineering and construction organizations.

Further details on candidates are available from the Secretary's office. Any member who wishes these biographic data need only request them.

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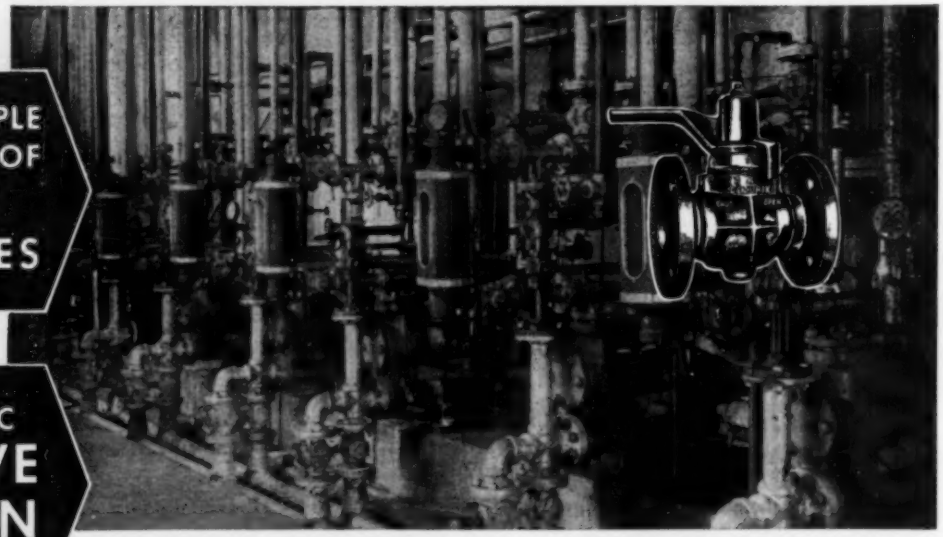

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SHORTAGE OR NO SHORTAGE?

Manpower Question Investigated

To help determine once and for all if there is or is not a shortage of scientific and engineering manpower, The National Science Foundation has just completed a survey of the research and development staffs of 200 leading companies, companies employing over half the research scientists and engineers of the country. While confined to research personnel, results form a good indication of the actual situation.

Conclusion: There is a manpower shortage in science and engineering, but it varies between companies and industries, is more acute with certain specific experience-education levels.

Approximately half the companies quizzed in the chemicals and allied products industries reported shortages of scientists and engineers. With all these companies stress was placed on the necessity to undertake intense recruitment programs, face strong competition for qualified personnel.

While all types and levels of chemical engineers are needed, a special need appears to be for engineers with 1 to 5 years industrial experience. Still, a definite demand for recent graduates was indicated.

One of the most notable facts was the continual emphasis given to "quality" among engineers and scientists. Many companies maintained that much of the shortage was caused by a lack of well qualified, well-trained people rather than an absolute shortage. Men with experience or top-level academic records are most desired. □

In-plant training courses, provided they are of graduate caliber, should be accreditable toward advanced degrees in engineering or science, R. C. Kintner, professor of chemical engineering, Illinois Institute of Technology, told the American Society for Engineering Education at the Society's recent annual meeting at Pennsylvania State University.

Kintner admitted that in-plant courses given by industrial organizations do not always meet the academic standards of graduate schools, but once such standards are met the school should accept the course work for credit exactly as it would a course from another graduate school. □

Chemical aspects of nuclear energy will be the subject of a new course at Illinois Institute of Technology this fall.

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INDUSTRIAL NEWS

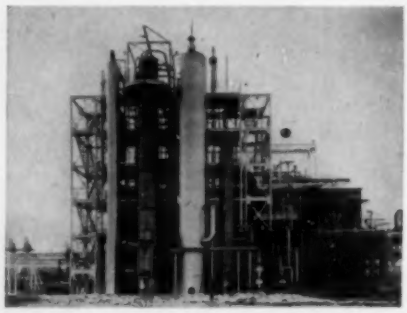
World's largest industrial data reduction system will be built by Fischer & Porter Co., Hatboro, Pa., for the ultramodern Canadian Petrofina Ltd. refinery soon to go into operation in Montreal, Canada.

The planned Automatic Logger—a $50,000 installation—will automatically monitor, analyze and record a total of 480 process variables for all nine production units at the Canadian refinery, will go on-stream in November.

Under normal conditions, the unit automatically types out on a single log sheet the value of all variables each hour on the hour, scans all variables between logging hours, reports selected or abnormal conditions. In case of trouble, the Logger signals an alarm and immediately types the out-of-line condition and its location.

In addition to recording raw data, the Logger is designed to automatically compute and record more complex factors of interest to refinery operating personnel—such as total flow, efficiency ratios and yield factors—and to punch significant data directly into paper tape or cards to facilitate subsequent analysis by Petrofina's accounting and engineering departments, speed preparation of summary reports to management. ☐

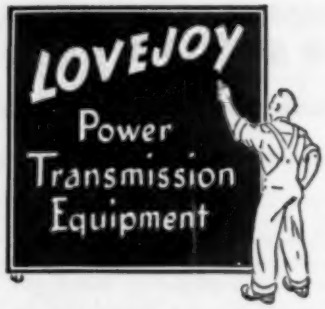
Ethylene oxide by direct oxidation will be major unit in new petrochemical facilities designed and engineered by the Scientific Design Co., New York, for the Societe Chemique des Derives du Petrole, Antwerp, Belgium.



In the plant scheduled to be completed in 1956, ethylene oxide and ethylene glycol will be only two of a variety of products manufactured from the gases of refineries in the Antwerp region.

The entire "petrochim" project is financed by eleven major Belgian corporations with $8 million, including a loan of $2 million from the Belgian Government. ☐

Pennsylvania Salt Manufacturing Co. has moved its executive offices to 3 Penn Center Plaza, Philadelphia, Pa. The address is also the headquarters of all Pennsalt's operating divisions. ☐



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INDUSTRIAL NEWS

Boost to international trade is new American Overseas Finance Corporation, giant financial institution jointly owned by Chase Manhattan Bank, Chemical Corn Exchange Bank, First National Bank of Boston, Mellon National Bank and Trust Company, National Bank of Detroit.

Designed to fill a gap which threatens to curtail U. S. export trade, the AOFC offers U. S. manufacturers and exporters the chance to extend longer-term credit to their customers abroad. At present, AOFC is confining its credit facilities to sales of productive capital goods only—the area where the greatest benefit to the well-being of the world can be realized. □

New mobile power unit operated by a newly designed combustion gas turbine directly connected to a generator and mounted on a single railroad car has been developed by Clark Bros., Olean, N. Y., one of the Dresser Industries.

Designed for the Navy as a source of emergency power, the power unit bears watching as a source of stand-by power for industrial companies. Developing 5500 KW of electric power, the unit is easily placed in operation. □

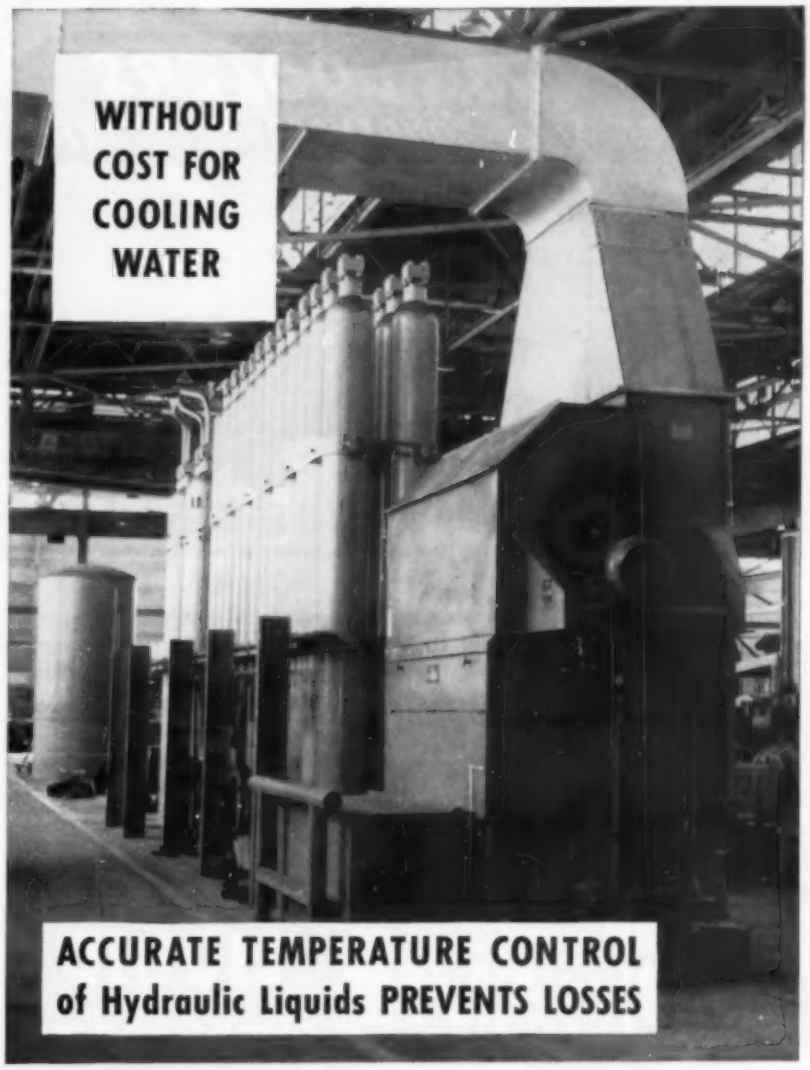
An ammonia fertilizer plant in southeastern Washington is to be constructed by newly formed Phillips Pacific Chemical Company, joint venture of Phillips Petroleum and Pacific Northwest Pipeline Corp.

Made possible by a long distance gas transmission line now under construction by Pacific Northwest to bring gas from the San Juan Basin of northwestern New Mexico and southwestern Colorado to the Pacific Northwest, the initial unit of the new plant will produce 200 tons per day of anhydrous ammonia, will be on stream late in 1956. □

Work will start soon on a gypsum wallboard and plaster plant in Burlington County, N. J. and the plant should be in production within a year. Plant will be the 38th in the National Gypsum chain, will employ upwards of 400 workers with an annual payroll of more than $1 million.

The plant will be located on the Delaware River to enable the company to bring large cargo ships directly to the plant.

National Gypsum is now developing the largest gypsum deposits in North America near Halifax, Nova Scotia, and the rock will be transported to the new plant in 15 thousand-ton cargo ships now under construction in Germany. □



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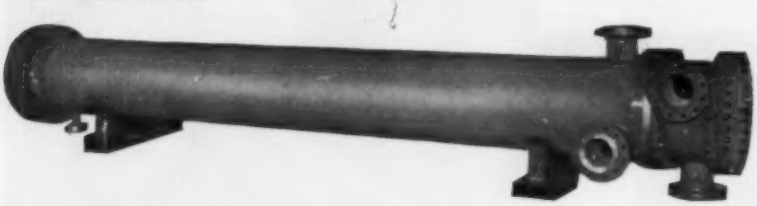

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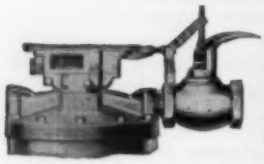
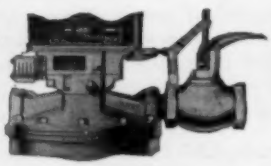


Repeating dial delivers predetermined, repeating quantities automatically.



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FUTURE MEETINGS and

Note: The Author Information column will appear quarterly in the January, April, July and October issues.

MEETINGS **SYMPOSIA**

■ **LAKE PLACID, N. Y.**

Sept. 25-28, 1955. Lake Placid Club.

A meeting devoted to the problems of interest to top management.

See general program on page 33 of this issue.

■ **ANNUAL—DETROIT, MICH.**

Nov. 27-30, 1955. Statler Hotel.

TECHNICAL PROGRAM CHAIRMAN: T. J. Carron, Supervisor, Chem. Eng. Section, Ethyl Corp., Res. Labs., 1600 West Eight Mile Road, Detroit 20, Mich.

Experiences in Nuclear Engineering Education

CHAIRMAN: R. P. Genereaux, Eng. Dept., Dupont Co., Wilmington, Del.

Biochemical Engineering

CHAIRMAN: H. O. Halvorsen, Dept. of Bacteriology, Univ. of Illinois, 362 Noyes Lab. of Chem., Urbana, Ill.

Technical Societies Cooperation with Chemical Engineering Industries

CHAIRMAN: J. B. Phillips, Dept. Chem. Eng., Phys. Sciences Centre, McGill Univ., Montreal 2, Canada.

Mechanics of Bubbles and Drops

CHAIRMAN: R. C. Kintner, Dept. Chem. Eng., Ill. Inst. of Tech., 3300 Federal St., Chicago 16, Ill.

Standardization of Centrifugal Chemical Pumps

CHAIRMAN: C. J. B. Mitchell, Engineering Service Div., Eng. Dept., E. I. duPont deNemours Co., Inc., Wilmington, Del.

Evaporators

CHAIRMAN: W. L. Badger, 309 S. State St., Ann Arbor, Mich.

Liquid Metals in Chemical Industry

CHAIRMAN: C. F. Bonilla, Dept. of Chem. Eng., Columbia U., New York 17, N. Y.

Deadline Past

■ **LOS ANGELES, CALIF.**

Feb. 26-29, 1956. Statler Hotel.

TECHNICAL PROGRAM CHAIRMAN: T. Weaver, Proc. Eng., The Fluor Corp., Ltd., Box 7030, East L. A. Station, Los Angeles 22, Calif.

New Techniques for Utilization of Fast Reactions & Freezing of Equilibria

CHAIRMAN: W. H. Corcoran, Cal. Inst. of Tech., 1201 E. Cal. St., Pasadena, Calif.

Current Status of Completely Automatic Process Units

CHAIRMAN: F. C. Brunner, C. F. Braun & Co., 1000 S. Fremont Ave., Alhambra, Calif.

Supervision of Technical Personnel (Panel)

CHAIRMAN: R. D. Gray, Cal. Inst. of Tech., 1201 E. Cal. St., Pasadena, Calif.

Techniques of Economic Justification for Process Industry Projects

CHAIRMAN: H. E. Wessel, Interna'l. Minerals & Chem. Corp., 20 N. Wacker Dr., Chicago, Ill.

MEETINGS **SYMPOSIA**

AIR POLLUTION

CHAIRMAN: H. P. Munger, Syracuse Univ., Syracuse 10, N. Y.

Deadline—Oct. 26, 1955

■ **NEW ORLEANS, LA.**

May 6-9, 1956

TECHNICAL PROGRAM CHAIRMAN: H. E. O'Connell, Assoc. Dir. Process Div., Sect., Ethyl Corp., Box 341, Baton Rouge, La.

Fundamental Mechanism in Boiling, Cavitation and Condensation

CHAIRMAN: R. R. Hughes, Shell Dev. Co., Emeryville, Calif.

Foreign Chemical Developments & their Effect on U. S. Chemical Industry

CHAIRMAN: C. W. Humphreys, Shell Chem. Corp. 50 W. 50th St., New York, N. Y.

UNSCHEDULED SYMPOSIA

Extraction of Hydrocarbons for Chemical Use from Pipeline Gases

CHAIRMAN: E. E. Frye, J. F. Pritchard & Co., 210 W. 10th, Kansas City 5, Mo.

Distillation Computation Methods

CHAIRMAN: Wayne C. Edmister, California Res. Corp., Richmond, Calif.

Operations Research

CHAIRMAN: George D. Creelman, Creelman Assoc., 2245 Harcourt Dr., Cleve., O.

■ **GALVESTON, TEXAS**

Oct. 14, 1955. Galvez Hotel

One-day Technical Meeting of the South Texas Section (10th Annual).

CHAIRMAN: W. L. Bolles, Monsanto Chemical Co., Texas City, Tex.

PROGRAM CHAIRMAN: Earl Manning, Shell Oil, Houston, Tex.

■ **NEW YORK, N. Y.**

Oct. 20, 1955. Hotel Statler

One-day Technical Meeting, N. Y. Section of the A.I.Ch.E.

CHAIRMAN: T. M. Jackson, Jr., Johns-Manville, New York, N. Y.

■ **CHARLOTTESVILLE, VA.**

Oct. 21, 1955 U. of Virginia

Half-day symposium on "Drying" sponsored by the Central Virginia Section of the A.I.Ch.E.

SYMPOSIUM CHAIRMAN: S. J. Friedman, DuPont, Waynesboro, Va.

Contact Chairman by August 1 to submit paper for symposium.

■ **CLEVELAND, OHIO**

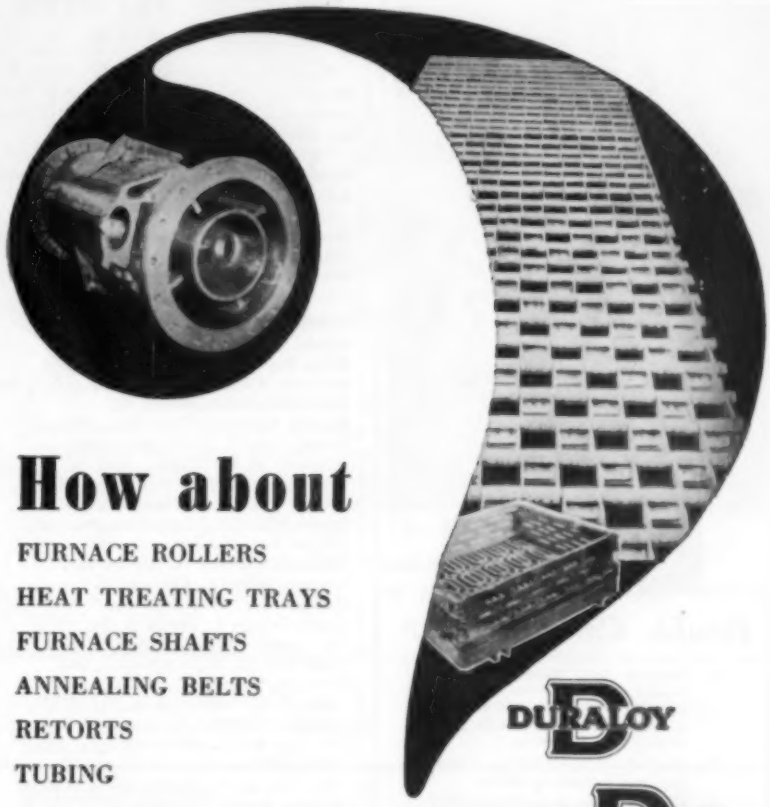
Dec. 12-17, 1955. Cleveland Auditorium.

EJC Nuclear Eng. & Science Congress

PROGRAM CHAIRMAN (A.I.Ch.E.): W. K. Woods, General Electric Co., Richland, Wash.

Liquid Metals in Nuclear Power

CHAIRMAN: C. F. Bonilla, Dept. of Chem. Eng., Columbia U., New York 17, N. Y.



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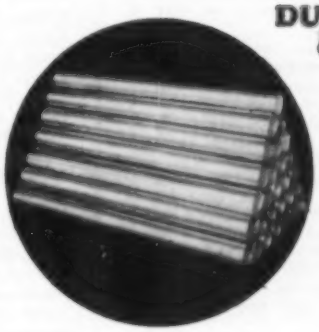

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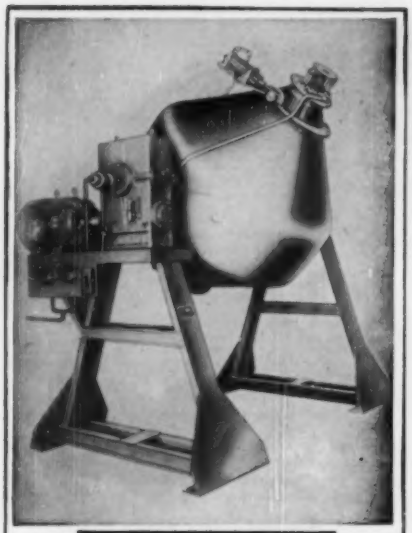

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The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on admissions.

These names are listed in accordance with Article III, Section 8, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members will receive careful consideration if received before September 15, 1955, at the office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

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Bair, Wilford G., *Chicago, Ill.*
Beattie, Robert D., *Cambridge, Mass.*
Berber, John S., *Indian Head, Md.*
Bhagwat, M. R., *Niagara Falls, N. Y.*
Bottenfield, Baird F., *Oak Ridge, Tenn.*
Braden, Dean E., *Richland, Wash.*
Brown, Wilson D., *Havertown, Pa.*
Clarke, Frank E., *Annapolis, Md.*
Collender, Edward H., *Bishop, Tex.*
Cooper, Robert I., *Chicago, Ill.*
Cowan, A. V., *Pittsburgh, Pa.*
Crain, George L., *Lafayette, La.*
De Marchi, Vincent S., *Jamaica, N. Y.*
Duff, Alan D., Jr., *Wilmington, Del.*
Eckerson, William H., *Dumas, Tex.*
Falck, E. L., *New York, N. Y.*
Giacco, Alexander F., *Kenvil, N. J.*
Gholson, Roy L., *Fairbanks, La.*
Hecht, William J., Jr., *Hopewell, Va.*
Hess, George H., *Trona, Calif.*
Holmes, Robert C., *Aiken, S. C.*
Hudson, William B., Jr., *Ramsey, N. J.*
Hunter, James H., *Pasadena, Tex.*
Jones, Edward Lewis, *Covina, Calif.*
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Moen, Rolf, *Minneapolis, Minn.*
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Nelson, Lawrence Earl, *Portsmouth, Va.*
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Street, John P., *Pasadena, Tex.*
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Welbourn, John A., Jr., *St. Albans, W. Va.*
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West, A. Sumner, *Philadelphia, Pa.*
Wetzel, Otto K., Jr., *Dallas, Tex.*
Wilker, Thomas A., *Texas City, Tex.*
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Aha, John P., *Portland, Ore.*
Alexander, Joe M., *Anderson, S. C.*
Alexander, Mark Alfandary, *Pittsburgh, Pa.*
Almaula, B. C., *Trona, Calif.*
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Barber, William E., *Clare, Mich.*
Bardawil, Labib P., *Beirut, Lebanon*
Baugh, John Ernest, Jr., *Monroe, La.*
Berman, Neil S., *Milwaukee, Wis.*
Bishop, James E., *Bridgeville, Pa.*
Bochman, Raymond A., Jr., *Somerville, Mass.*
Bolen, Kenneth E., *Jackson, Ala.*
Boss, Richard A., *Glens Falls, N. Y.*
Boyd, William E., Jr., *Gladewater, Tex.*
Boykin, R. G., *Sylacauga, Ala.*
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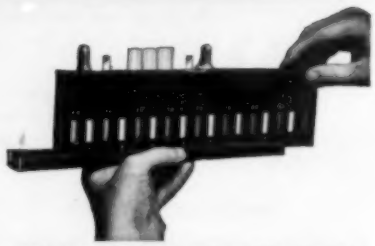

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(Continued on page 76)

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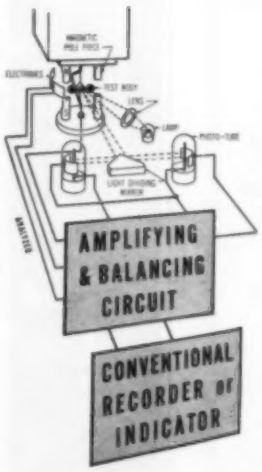

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***Note:** For ranges narrower than 0-5% O_2 ask about the Model G2.*

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ATOMIC EXPOSITION IS INTERNATIONAL

—20 English Firms to Exhibit

—57 A.I.Ch.E. Papers at Congress

High interest in America's first International Atomic Exposition, sponsored by A.I.Ch.E., is bringing foreign countries to exhibit in large numbers. England alone already has 20 firms preparing to exhibit their wares, ideas, and progress in peacetime atomic energy at the December gathering in Cleveland.

This is more companies than the U. S. will have represented at the commercial exhibit in Geneva, and represents the first opportunity for American industry to get a first-hand picture of England's atoms-for-peace program.

In addition, Harwell, England's equivalent of Oak Ridge, will participate in the concurrent Nuclear Congress.

At the Congress, 57 papers in all will be presented by A.I.Ch.E. members, covering all possible engineering aspects of nuclear energy. Too numerous to be detailed here, some high spots will be the Liquid Metals in Nuclear Power symposium, chairmaned by C. F. Bonilla, the paper on Continuous Processing of Heterogeneous Reactors by H. H. Hyman and J. J. Katz of the Argonne National Laboratory, Unusual Problems of Reactor Instrumentation by T. R. VickRoy, Du Pont, the symposia on Heat Transfer and Fluid Flow, Reactor and Coolant Technology, Catalysis and Chemical Reactions, Materials and Metallurgy, Chemical Processing and Separation, Research Reactors and Radiation Laboratories, all of which are predominantly made up of A.I.Ch.E. papers.

Pre-registration forms, as well as hotel registration forms and preliminary program, will be ready for mailing by Engineers Joint Council in mid-September. □

Six prominent A.I.Ch.E. members are among the technical advisors to the United States delegation at the International Conference on the Peaceful Uses of Atomic Energy now in progress at Geneva, Switzerland. They are: M. Benedict, MIT; L. E. Brownell, Univ. of Michigan; B. Manowitz, Brookhaven National Laboratory; J. J. Martin, Univ. of Michigan; C. R. McCullough, Monsanto; and W. K. Woods, Hanford Atomic Products Operation. □

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WORLD PETROLEUM CONGRESS

— Picture on Petroleum Today

More than 4000 engineers and scientists of the petroleum industry journeyed to Rome, June 6 to 15, to share knowledge of recent developments, trends, and future of petroleum and the field of energy sources in general.

Result: Spotlight on rapid development of petroleum utilization since World War II, recent strides in petroleum engineering.

Running through all talks, discussions and meetings at the Fourth World Petroleum Congress in Rome in June was the two-fold growth of the petroleum industry—as a major energy source, as the backbone of the booming petrochemical industry.

The more than 4,000 representatives from over 30 countries presented their views primarily in the form of technical reports, over 200 in all, covering every aspect from geology and drilling, through chemicals and analysis, to utilization and construction.

Leading the U. S. delegation was E. V. Murphree, president of Esso Research and Engineering and a director of A.I.Ch.E. Other A.I.Ch.E. members from the U. S. were J. K. Roberts, H. W. Field, W. M. Holaday, M. E. Spaght, and H. G. Vesper.

While it was plain that world consumption of petroleum is increasing rapidly, high in U. S. and almost double the U. S. rate outside America, and will tend to continue to increase, the sister field of petrochemicals is using so much oil that considerable attention was given to other fuel sources—notably atomic energy. The U. S., well supplied with cheap hydro-electric power, oil and other energy sources, is not likely to plunge into atomic energy as a fuel source in the immediate future. But other countries, not so well endowed, such as England, France, Italy, and some Scandinavian countries, may well take important steps in this direction within five years. If they do, the world petroleum picture will be affected.

Perhaps the main result of the Congress, apart from the exchange of knowledge and know-how, was the definite sense of great scientific and engineering strides being made by the Western nations.

The free-world is awakening rapidly to the necessity for better utilization of energy supplies, better harnessing of oil's great versatility as a chemical raw material basic to economic development.

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December 12 through 16

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Chemical Engineering Progress

UNDER the coordination of the Engineers Joint Council, nuclear scientists and engineers of 24 industrial and scientific groups and engineering societies will convene at the Nuclear Congress in Cleveland for five historic days beginning December 12. They will hear and discuss more than 290 significant papers presented by leading atomic experts on new developments in the application of nuclear energy to industrial and other uses.

Over 45 of these papers will be presented under the sponsorship of the A.I.Ch.E. These papers will deal with subjects of interest to every Chemical Engineer concerned with nuclear energy. In addition, the Congress will give every A.I.Ch.E. member the rare opportunity of meeting and talking with the nation's foremost nuclear authorities in allied fields of engineering.

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The exposition will open Saturday, December 10, two days in advance of the Congress. Here is your best chance to evaluate new products and developments, get the facts first hand on application data, and talk shop with your contemporaries.

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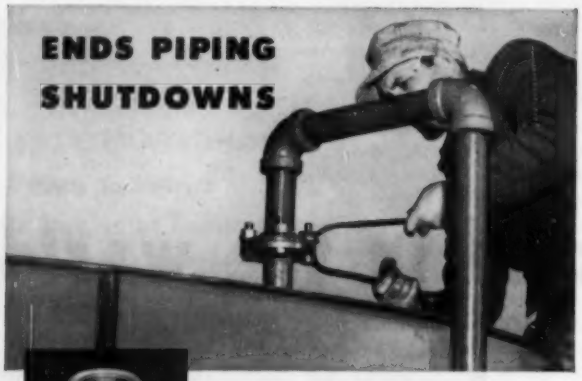

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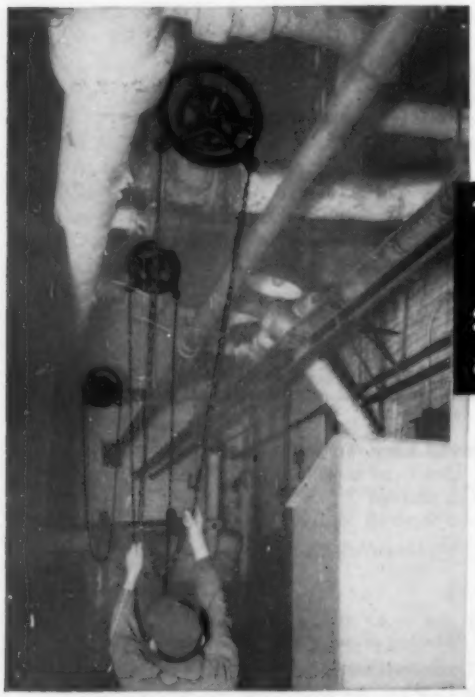

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Miley, George H., II, *Petrolia, Pa.*
Miller, Irvin M., *Oak Ridge, Tenn.*
Millman, Arthur, *Edge Moor, Del.*
Mullen, Edward L., *New York, N. Y.*
Murphy, Frank B., *Pitcairn, Pa.*
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Muth, David Philip, *Cactus, Tex.*
Myles, Kenneth E., *Naperville, Ill.*
Nesbitt, Ray Ben, *Baytown, Tex.*
Nielsen, Marvin F., *Dallas, Tex.*
O'Connell, Wilbert, Jr., *Baden, Pa.*
Olcott, Victor G., *Mt. Vernon, N. Y.*
Oster, Robert A., *Galveston, Tex.*
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Pagano, Frank, *Paterson, N. J.*
Pagel, David F., *Brillion, Wis.*
Palmer, David A., *Rowley, Mass.*
Papathakos, Leonidas, *Atlantic, Ia.*
Payne, Ralph O., *Knoxville, Tenn.*
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Pfister, Hansruedi, *Boston, Mass.*
Phillips, Robert E., *New York, N. Y.*
Pike, John R., *Maywood, N. J.*
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Platt, John, *Philadelphia, Pa.*
Potter, Richard N., *Fairport, N. Y.*
Quay, Thomas, *Phoenixville, Pa.*
Randolph, Harry E., *Floyds Knobs, Ind.*
Reed, David B., *Buffalo, N. Y.*
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Reis, Lloyd M., *Springdale, Ark.*
Resen, Frederick Lawrence, *Houston, Tex.*
Risch, Thomas A., *Milwaukee, Wis.*
Robinson, William L., Jr., *New York, N. Y.*
Roselius, Ronald R., *Richmond, Calif.*
Rosinski, Jan, *Chicago, Ill.*
Salzman, Paul K., *Brooklyn, N. Y.*
Samolis, Robert, *Cleveland, Ohio*
Sanders, Aubria A., Jr., *Baytown, Tex.*
Schafer, Richard E., *St. Albans, W. Va.*
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Suarez, Alfonso, *Hamilton, Ont., Canada*
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News of the Field
FROM LOCAL SECTIONS

Southern California. The engineer's training should be supplemented by training and interest in what makes people think and react to stimuli, said H. L. Coderre, an industrial psychologist, to the April 19 meeting of the Southern California Section.

Engineers have always shown a great proficiency in developing and handling data, but this aptitude has not been reflected enough in their relationships with other engineers, with their superiors and their subordinates.

This fault is of growing importance today. Human relations will continue to be of increasing importance as more and more engineers advance to management positions. The ability to know when to rely on the judgments and opinions of others can, in the long run, be of more importance than the evaluation of facts.

At this meeting, the Section also heard a report alerting members to legislation under consideration in California that could affect their professional status.

—F. G. SAWYER

East Tennessee. A discussion of the operations of the lithium plant operated at Sunbright, Va., by the Foote Mineral Company, was presented to the May meeting of the East Tennessee Section by E. L. Remesch, plant superintendent of the Sunbright installation.

—P. C. UNDERWOOD

Knoxville, Tenn. The concept of a fourth state of matter, the vitreous, was considered by J. R. Johnson, Oak Ridge National Laboratory, during his talk on "The Nature of Glass" to the June 1 meeting of the Knoxville-Oak Ridge Section.

In pointing out that glass is neither a solid nor a liquid, Johnson said it is often considered to be a fourth state, i.e. vitreous. A characteristic of a vitreous material is a *random* network of tetrahedral molecules, SiO_2 being an example.

Particularly useful were Johnson's illustrations of the effects of irradiation on glass, which changes its properties, and of special heat treatment to produce compression on the surface of the glass, which increases its strength to a remarkable extent, enabling Johnson to use a piece of glass pipe as a hammer to show its strength after pre-stressing treatment.

—R. J. MCNAMEE

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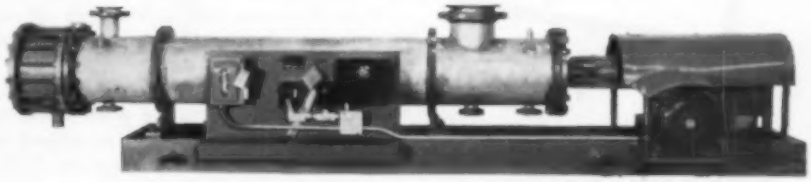

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News of the Field
FROM LOCAL SECTIONS

Philadelphia-Wilmington. There are four basic types of industrial explosives based on nitroglycerine: straight and ammonium nitrate dynamites; straight and ammonium nitrate gelatine, according to W. J. Taylor, Jr., Explosives Department, Atlas Powder. Speaking before the April 12 meeting of the Philadelphia-Wilmington Section, Taylor discussed basic explosives, new developments in blasting techniques, and special explosives and charges.

There are two broad types of explosives: burning types, such as black powder, and detonating explosives, such as TNT, cyclonite, and dynamite. Difference is strictly a matter of physical phenomena. Chemical reactions involved in explosions are characterized by the production of hot gaseous products. In burning, these reaction products move away from the actively reacting zone. In detonation, the gaseous products move into the reacting zone, building up tremendous pressures. Rate of burning is dependent upon the ambient pressure and the area of the surface undergoing reaction. Rate of detonation in a sufficiently large charge of high explosive is independent of surface area or pressure.

Most dynamites are made of four basic ingredients: nitroglycerine, a carbonaceous material to bind it and also produce gases, an oxygen supplier, such as sodium or ammonium nitrate, and a small amount of anti-acid material, such as zinc oxide or calcium carbonate.

Use of ammonium nitrate in place of earlier sodium nitrate is a late development based on four advantages of ammonium nitrate: (1) it is as good an oxidizing agent as sodium nitrate, (2) it completely decomposes into gaseous products which adds to the work-power of the dynamite, (3) when sensitized or boostered by nitroglycerine or TNT, ammonium nitrate is an explosive itself, (4) it is cheaper.

Rapid advances in blasting techniques in the last ten years, such as Atlas' short-delay blasting caps, as well as the use of such special explosive charges as shaped charges and powder-driven tools, closed Taylor's discussion.

—W. E. Osborn

Northern California. The prediction and control of weather under the heading of "Weather Engineering" was the subject of Edward Teller, renowned authority on theoretical physics from the Univ. of California, in his talk to the May meeting of the Northern California Section.

—T. E. Drisko, Jr.

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New York, N. Y. The problems of U.N. engineering teams in underdeveloped countries held the floor at the June 16 meeting of the New York Section. N. L. Macpherson, Chief of the Industrial Development Section of the U. N.'s Technical Assistance Administration, described the problems of engineering involved in establishing plants where none have been before, and the problems of working for an international body.

Transportation difficulties, equipment problems, the troubles of having to use manual labor for almost all jobs, and the differing ideas of proper and safe construction in different countries, all add to the engineer's headaches in trying to develop underdeveloped countries.

A major problem faced by engineers working for the U.N. is the purchase of equipment—where to buy it, etc.—and the natural reluctance of exporting countries to favor a local plant in a country which imports their material. But, Macpherson emphasized, only when a country is caught-up materially will it catch-up politically and socially, and this gives us all a big stake in developing backward countries. Much has been done by the U.N. and other agencies, both national and international, but much remains to be done. The total bill for international health problems, a mandatory adjunct of any industrial development, is about the same as the normal New York City snow removal bill for one winter.

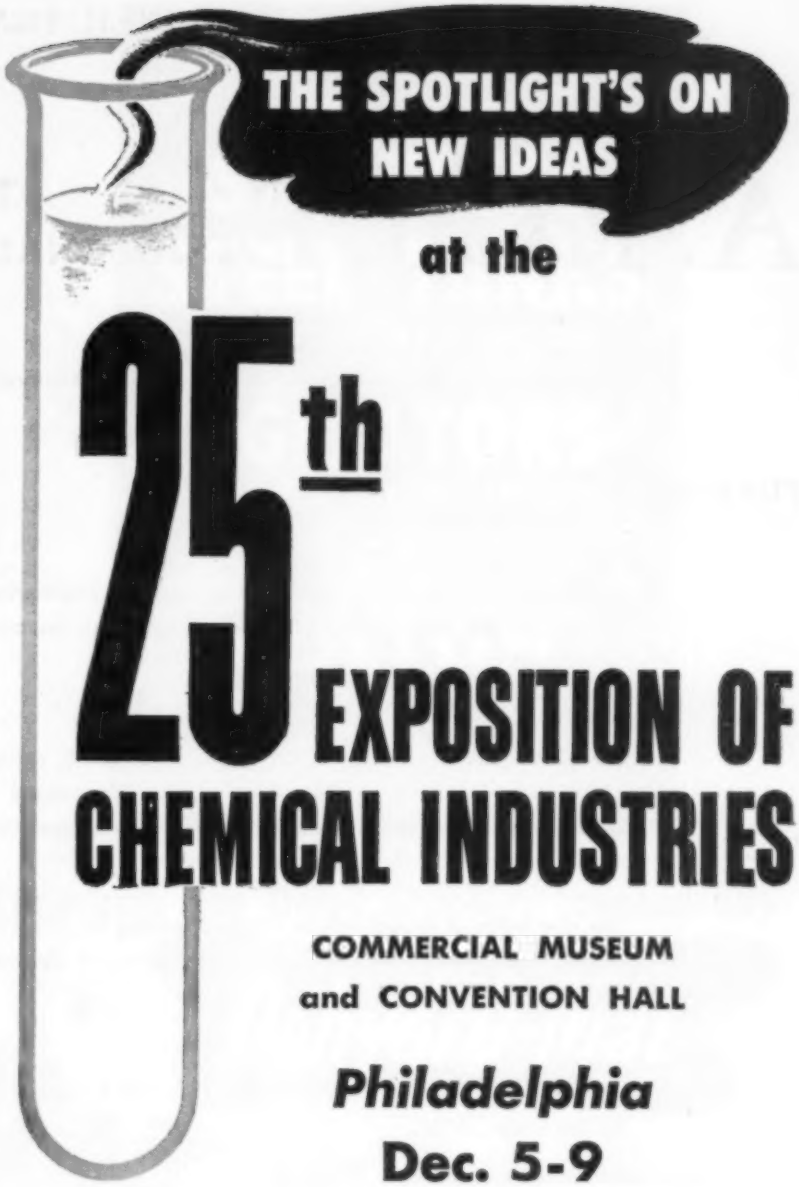
As for the problems of exporters, Macpherson pointed out that the only answer is that eventually the overall trade picture will greatly improve by bringing these countries into the industrial world.

—S. Adler

Charleston, W. Va. If you have extremely complex computing problems that recur regularly, and therefore involve a large number of identical calculations, automatic digital computers are probably the answer. In capsule, this was the conclusion presented by P. H. Sterbenz, International Business Machines Company, to the April meeting of the Charleston (W. Va.) Section.

In describing the basic principles of these computers, Sterbenz pointed out that the programming, or setting-up, of the machine to solve, say, 50 simultaneous equations may require several man-weeks. After this the machine is prepared to solve any such problem in 50 or less variables with little additional work. But the length of time required to set the machine makes it all but mandatory, economically, to have a large number of identical calculations to work out.

—R. W. Timmerman



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SEPTEMBER, 1955

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News of the Field

FROM LOCAL SECTIONS

Tulsa, Oklahoma. Priceless engineering data is useless unless it is clearly communicated to others. To do this, engineers must learn to express themselves better, and this formed the theme of the May 11 panel meeting of the Tulsa Section.

After J. W. Kilmer of Standard Oil and Gas, the moderator, had analyzed the general problem of the importance of expression in engineering, and L. F. Zimmerman, Univ. of Tulsa, had discussed the teacher's point of view on technical writing, the panel took up the four basic types of writing an engineer will be called on to do sometime during his career. Engineering report writing was presented by H. R. Jones, Chemical Plants Division, Blaw-Knox; research report writing by M. J. Rzasa, Cities Service Research & Development Co.; financial writing by B. R. Carney, Warren Petroleum Corp.; and the writing of articles for magazine publication by G. L. Farrar, *Oil & Gas Journal.*

As an aid to judging the level of an engineer's own writing, Farrar presented an interesting formula.

$$R = 0.4\,(L + P)$$

Here, R is the grade level of the writing (12, high school senior; 13 college freshman), based on L, the average number of words in a sentence, and P, the number of 3 or more syllable words per 100 words.

—J. H. KELLY

Cleveland, Ohio. A plant trip through No. 1 refinery of Standard Oil of Ohio was the May 24 meeting of the Cleveland Section.

After inspecting the plant processes and equipment, the meeting discussed the economics of Sohio's operation. G. R. Thompson, general superintendent, showed how the consumer's dollar was spent on Sohio's products, and how Sohio in turn spent that dollar to produce its products.

—J. L. MILLER

Louisville, Ky. Reaction rates involved in three basic types of reactors were discussed at the May meeting of the Louisville Section. The speaker, T. E. Corrigan, Olin Mathieson Chemical, led the way with the problems of kinetics in batch reactors, longitudinal continuous reactors, and continuous batch reactors. He paid particular attention to the effect of back-mixing, found in the continuous batch reactor, on product distribution and reactor size.

—F. G. SMITH, JR.

people

IN MANAGEMENT AND TECHNOLOGY

Margaret H. Hutchinson, first woman member of the A.I.Ch.E., was given the annual award of the Society of Women Engineers for "outstanding achievement in engineering." She is distinguished also as the only woman having received the Sc.D. degree in chemical engineering from M.I.T. She is with Stone & Webster Engineering Corp., N. Y.

Russell J. Cameron and **John B. Jones, Jr.,** have formed an engineering and consulting firm specializing in oil-shale technology. Both men have extensive experience in the field having held senior staff positions in the U. S. Bureau of Mines oil-shale experiment station. Cameron and Jones headquarter in Englewood, Colorado.

Clifford L. Sayre, development chemical engineer for Becco Chemical division and other chemical divisions of Food Machinery and Chemical Corp., is appointed Brigadier General, U. S. Chemical Corps Reserve. He is the first reserve officer to attain the rank of General in the Chemical Corps.

The following are recent staff changes made by Monsanto Chemical Co.: **Fred J. Holzapfel,** technical service supt., J. F. Queeny plant . . . **Jack W. Graves,** technical service supt., W. G. Krummrich plant . . . **James R. Moore,** project supervisor, development dept., overseas division . . . **J. C. Garrels,** asst. general manager, plastics division . . . **H. K. Eckert,** dir. of manufacturing, Texas City . . . **Carl E. Pfeifer,** dir. of manufacturing in Springfield . . . **J. S. Putnam,** plant manager, Texas City.

Announced also is the election of **R. K. Mueller,** vice-president of the company and general manager of the plastics division, as a divisional vice-president of the American Management Association in charge of the manufacturing division.

Frederick W. Gander, a research supervisor for Du Pont, is named research manager of the Yerkes Research Lab in Buffalo.

Harold L. Maxwell, in the company's engineering dept., received an honorary Sc.D. degree from Cornell College, Iowa.

(*Continued on page* 82)

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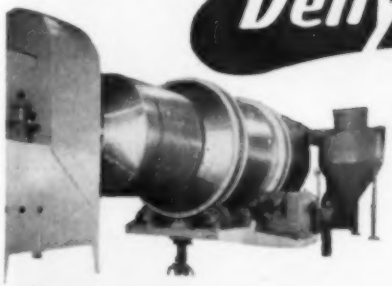

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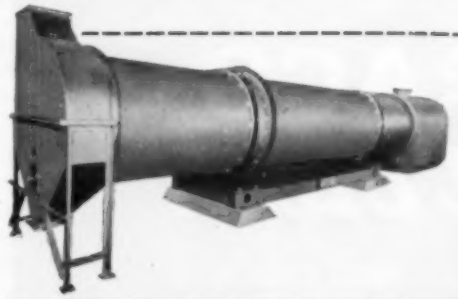

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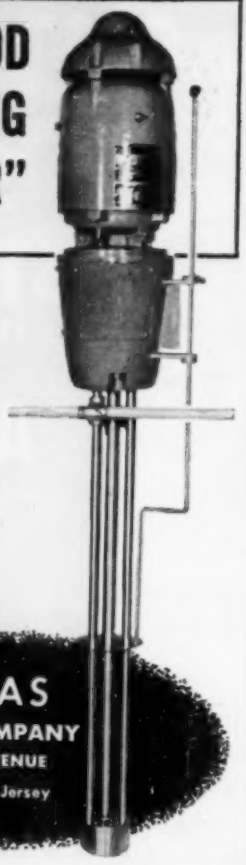

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IN MANAGEMENT AND TECHNOLOGY

(*Continued from page* 81)

The Chemstrand Corp. announces appointment of **Roy G. Hemminghaus,** pictured here, to newly created position of vice-president in charge of production. Hemminghaus will take over direction of operations at the company's nylon plant and the Acrilan acrylic fiber plant. At the same time Chemstrand names **Louis E. Dequine, Jr.,** to assistant plant manager of the Pensacola nylon plant.

Other advancements at Chemstrand include **Eugene Negro** to supervising project planning engineer, and **Vance O. Bonnichsen, John B. Charlton** and **George Malinoff** to be associated with Negro in the project planning section.

Monsanto Chemical Co. recently announced promotions of the following: **J. R. Durland** and **R. S. Wobus** to technical production managers in the organic chemicals division . . . **Howard L. Minckler,** plant manager at the John F. Queeny plant . . . **Joe Cresce,** plant manager at the William G. Grummich plant. **Robert E. Soden,** plant manager in W. Va. . . **Dominic Danna,** plant manager in Avon, Calif.

Elerington Saunders, Reginald N. Gonzalez and **Robert M. Morris** have been granted leaves of absence for university study.

J. S. Stanford, formerly assistant to the president, becomes vice-president of Varcum Chemical Corp.

Shell Chemical Corp. names **H. I. Wolff** asst. manager, manufacturing-development dept. Wolff will be responsible for coordination and guidance of plant improvement and expansion programs. He will supervise process evaluation and design of new products and processes.

William V. Brown joins research and development division of Davison Chemical Co., division of W. R. Grace & Co. to work in research engineering dept. at the Curtis Bay plant, Baltimore.

Hamnett P. Munger, technical research advisor for Battelle Memorial Institute, to chairman of chemical engineering dept., Syracuse U. Munger, author of over 20 articles on topics including air pollution and steel processing has been engaged in research in chemical and metallurgical engineering.

NUCLEAR ENERGY—REMOTE CONTROL

At the University of California's Los Alamos Scientific Laboratory, instrumentation techniques for remote control are highly developed—as can be seen in these significant pictures. Reason: High degree of danger in handling extremely radioactive materials, need for controlled means of putting together a critical amount of fissionable material.

Topsy, Godiva, and Jezebel, only critical assembly machines known to exist, operated by remote control, observed by television.

Remote control apparatus used to handle highly radioactive substances.

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Pla-Tank offers many advantages

The tanks are used for storing a 20% sodium hypochlorite bleach solution. PLA-TANK was chosen in preference to rubber-lined steel tanks for several reasons.

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- **PLA-TANK** prices compare favorably to rubber-lined steel.
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Charles E. Dryden, on a six-month leave from Ohio State U., will work with atomic power study group at General Electric Co., Schenectady.

Ju Chin Chu is spending summer with Rohm & Haas Co. as resident consultant at Huntsville, Ala., working as advisor in chemical engineering phase of rocket propellants and propellant systems. He is on leave from Brooklyn Polytech., New York.

John E. McKeen, president of Chas. Pfizer & Co., Inc., is awarded the Legion of Honor by the government of France in a ceremony inaugurating Pfizer's newly-built French plant for production of broad spectrum antibiotics Terramycin and Tetracyn.

Russell L. Bauer is process engineering supervisor in engineering dept. of Mobay Chemical Co. He was development manager, organic chemicals div., Monsanto Chemical Co.

American Viscose Corp. names technical supervisors: **Ben E. White,** textile yarns; **William P. Dooley,** staple and tow; and **Richard W. Bonnet,** tire yarns.

Nathaniel Brewer among four promoted to vice-presidents of Fischer & Porter. Brewer is in charge of the research division. **Robert A. Stern,** data reduction & automation; **Louis H. Arieson,** international division, and **Edward J. Querner,** manufacturing.

Herbert Kay to manager of new chemical development, chemical division of Climax Molybdenum Co. in charge of development of new chemical applications of Molybdenum.

W. O. Webber is technical specialist, technical service division at Baytown, Tex. plant of Humble Oil & Refining Co. to work on process design of light end recovery and processing facilities.

Henry W. Rojas to vice-president of

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PRACTICAL equipment has now been developed to effect the removal of contaminating iron from commercial hydrochloric acid, aluminum chloride, and comparable products. For many years, industry has looked on some iron content in these products as acceptable, though undesirable. In recent years, research chemists have shown in the laboratory that ionXchange *could* be used to remove such iron and produce water-white solutions. NOW Illinois Water Treatment Company has designed and built the *practical* equipment to accomplish this purpose *economically* on a commercial scale.

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the chemical engineer in
MARKETING

J. S. Wolff, pictured here, to field sales manager in the chemical sales dept. of B. F. Goodrich Chemical Co. He replaces **L. R. Modlin, Jr.** who has taken over as manager of general chemical sales. Modlin succeeds **R. P. Kenney** who recently became European director of chemical activities for the company.

Also among new appointments is **Edward N. Learner** to senior product engineer in charge of biochemical sales development. He joined the company in 1953 as a technical representative. Learner takes over sales development of biological, agricultural and industrial applications.

Harold M. Smith to assistant purchasing agent of Solvay Process division, Allied Chemical & Dye Corp.

Smith, with Solvay's engineering dept. since 1946, has spent the last six years in the textile section of technical service.

H. A. Voscamp, Jr. to head new thermoplastic sales group in Barrett division of Allied Chemical and Dye Corp.

Robert Powell, chemical engineer, among those to receive assignment change at Diamond Alkali Co. He is transferred to New York in field sales and service to replace **Robert R. Wood** who recently assumed position of special staff assistant in the sales dept.

Monsanto Chemical Co. appoints **Kenneth Conwell** district manager for the Houston, Tex. office of the company's organic chemical division. Also **Walter F. Waychoff** to technical sales specialist in this division.

Hooker Electrochemical Co. names three chemical engineers to sales staff. **George Chynoweth, Joseph J. Lenahan,** and **Julian Boyce** will assume new responsibilities as field sales representatives.

American Cyanamid Co. consolidates market research and new product development depts. with **Borden R. Putnam, Jr.** to head the combined activities. **Samuel D. Konnce** was named manager of market research and **James G. Affleck** becomes manager of new product development.

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Henry W. Rojas to vice-president of export marketing for Witco Chemical Co. With 28 years of worldwide chemical experience Rojas will be responsible for all present international operations and for export market development. He will headquarter in New York.

Earle S. Ebers to general sales manager, Naugatuck chemical division of U. S. Rubber Co. **D. Lorin Schoene** to director, research and development, and **F. Dudley Chittenden** is production manager. All appointments are in the Naugatuck division.

Robert T. Mills puts chemical engineering training to work as advertising manager of Pennsylvania Salt Manufacturing Co. He joined the advertising staff in 1949 having received his chemical engineering degree the year before from Drexel Institute.

Carl W. Eurenius to asst. general manager of the cellulose products dept. of Hercules Powder Co. He had been director of sales since 1948. **Werner C. Brown** succeeds Eurenius as director of sales.

With the establishment of three new sales depts. at the chemical division of Goodyear Tire & Rubber Co., **M. J. Rhoad** becomes manager, rubber and rubber chemicals dept., **A. E. Polson** is manager, plastics dept., and **John Warner** is asst. manager in the coatings dept.

Thomas J. Desmond to Chicago district sales manager of the Grasselli dept., the DuPont company.

Walter B. Lawrence to manage new Ohio sales district for Allis-Chalmers Manufacturing Co.

Charles M. Fletcher to manager of Philadelphia regional office of the Pflaudler Co.

R. P. Lee appointed senior engineer in charge of corrosion and materials engineering in development and engineering dept., National Lead Co.'s titanium division.

Marion E. Dice to assistant to the president of General Petroleum Corp. Dice had been manager of the economics dept. since 1944 and technical assistant to the president for one year. He is active in petroleum industry affairs.

S. G. Sevougian to manager of Dow Chemical Co.'s Framingham, Mass., plant. Sevougian has served Dow in several capacities since 1945.

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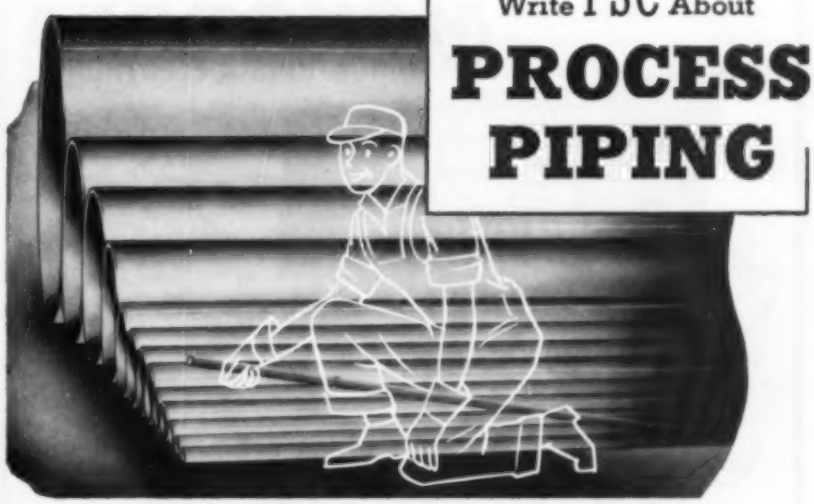

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CONTACT:

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Must have degree in chemical engineering; minimum of five years' experience in petroleum refinery design; capable of evaluating refinery operations and data, preparation of process calculations, process flow diagram and equipment specifications. Follow through on mechanical design of facilities. Will be expected to make independent analyses and exercise individual judgment. Please write to Chief Design Engineer and give full details of personal history and work experience. Provide references and include photograph.

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Young men with advanced degrees in chemical engineering or five years' experience in process design of oil refining or organic chemical processes. Opportunities directly concerned with evaluation of research projects and design of new process units based on refining and petro-chemical research and development. Write giving education, experience and personal history to Employment Supervisor

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CHEMICAL ENGINEER—B.S., M.I.T. Five years' experience in process and product development, economic evaluations. Age 28, veteran, sales type of personality, can handle people. Desire position in engineering liaison, administration, or technical sales with a growing company. Box 13-8.

CHEMICAL ENGINEER—Ph.D., age 33. Diversified experience in production, process development, process design, project engineering, teaching. Can handle contact work. Now successfully handling responsible industrial position but ready for greater responsibility with progressive company. Box 14-8.

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CHEMICAL ENGINEER—B.S.Ch.E. 1951. Veteran, age 32, family. Four years' diversified experience in production, pilot plant, process control. Desire change to challenging position in physics engineering. Interests: chemical or nuclear propulsion developments, high altitude engineering, and related fields. Box 16-8.

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PERMANITE is a *furfuryl alcohol resin* reinforced with Chemical Fibreglass. It is light weight, strong and tough with a hard, non-absorbent surface and is corrosion-proof throughout. It handles all alkalies, most acids including HCl and HF, oils and organic solvent vapors. Some examples of Permanite Equipment we have made include:

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Write for Bulletin No. 6-F.
Permanite Equipment.

MAURICE A. KNIGHT
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Acid and Alkali-proof Chemical Equipment

Necrology

Chemical Engineering Progress announces with regret the death of the following members of the profession.

Kenneth A. Reeve, 49, engineering supervisor, Knolls Atomic Power Lab, General Electric Co.

Charles B. Durgin, 60, asst. to plant manager, Monsanto Chemical Co., Anniston, Ala.

John H. Thompson, 56, chemical engineer, U. S. Dept. of Agriculture, Bureau of Industrial and Engineering Chemistry, Western Regional Research Lab.

Frank D. Oldham, 43, chairman of the dept. of chemical engineering, U. of Missouri.

Oldham joined the Missouri U. faculty after spending several years in industry in capacities including his position in the gas processes division of the Girdler Corp. Along with his duties as professor, Oldham served also as consulting engineer with the TVA, and a number of industrial firms.

The Southern California Industrial Research Center has been established as part of the Univ. of Southern California in a move to make the extended and expanded services and facilities of the university available to Western business and industry.

Program of the Center will include basic research, contract research, graduate training for company personnel, recruitment of pre-college students into engineering programs, and information and library services. In addition, SCIRC will maintain a reservoir of scientific personnel who will conduct symposia and publish materials available to SCIRC members.

New officers of the Chemical Institute of Canada are: Roger Gaudry, Ayerst, McKenna & Harrison Ltd., president; C. B. Purves, McGill Univ., vice-president; F. K. Rogers, Shawinigan Chemicals Ltd., chairman of the board; T. H. G. Michael, Howards & Sons (Canada) Ltd., treasurer; G. T. Page, general manager and secretary. □

More educational interest to nuclear engineering is shown by Brooklyn Polytechnic Institute's first nuclear option for senior chemical engineering students, first course this fall. In addition, Brooklyn Poly is also starting to offer nuclear work on the graduate level. □

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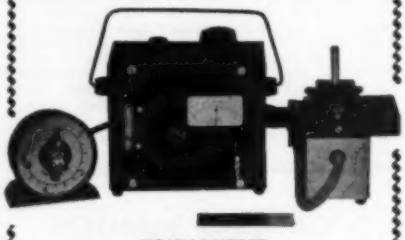

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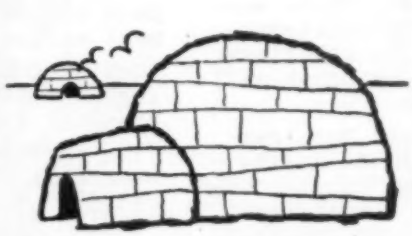

C-R CHILL-VACTOR units flash cool water, aqueous solutions and certain other liquids to temperatures down to 32° F. by partial evaporation at high vacuum.

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news and notes

INDUSTRY-SPONSORED SCHOOLS are another A.I.Ch.E. effort, under the guidance of the Chemical Engineering Projects Committee . . . Idea is to have various members of chemical engineering faculties visit industrial firms where officials describe problems, activities, & needs & explain how training & education can help . . . Last year such a school was held by the Vulcan Copper & Supply Co., Cincinnati, Ohio . . . well over half a dozen schools have been held in Texas; Shell Development held one at Berkeley; another was held by TVA . . . All this from a report by R. C. Kintner, chairman of the Projects Committee.

SELECTIVE SERVICE and allied problems for all engineers are being handled by the Engineering Manpower Commission of Engineers Joint Council. . . . The five engineering societies are cooperating in this move, which is guided by W. T. Cavanaugh, executive secretary of the E.M.C. . . . He is well versed in Selective Service lore, & should any A.I.Ch.E. members have problems concerning military service, etc., a letter to the secretary of the A.I.Ch.E. or to Mr. Cavanaugh will bring prompt advice.

COMMITTEE MEETINGS at National Meetings are becoming more popular in the Institute . . . They avoid that last minute jam-up at year end when so many committees have so much business to accomplish that interference with other activities is inevitable.

LIQUID METALS TECHNOLOGY will be the subject of two technical sessions under the chairmanship of C. F. Bonilla of Columbia . . . The nonnuclear aspects of liquid metals will be explored at the Detroit meeting this year & a symposium on the nuclear uses will be held at the Nuclear Congress in Cleveland this December.

STUDENT GUIDANCE COMMITTEE OF THE NEW YORK SECTION OF THE A.I.Ch.E. provides an excellent example of the help individual members can give to chemical engineering . . . This committee with the help of representatives from other engineering societies explains engineering as a career to high school students . . . Thirteen members of the local section already have filled twenty-three speaking engagements at high schools in & around New York City . . . Morgan M. Hoover, associate editor of our friendly competitor Chemical Engineering, is chairman of the group this year.

LAPEL BUTTON pictured at the head of this column was made available early this year . . . Quite a number have been sold at $1 each & any member who wants one should either write directly to this office or pick one up at the registration desk at the next A.I.Ch.E. meeting he attends.

UNIVERSITY OF CINCINNATI Student Chapter is sponsoring a program of making special loans to college students . . . William Licht, head of the chemical engineering department at the university, writes to say that the student chapter obtains money for the grants & loans from the candy & soft drink canteens that it operates . . . Sufficient income is obtained in this way to make possible also an award of $100 to the outstanding member of the senior class each year . . . The award is named for R. S. Tour, former head of the chemical engineering department at the university.

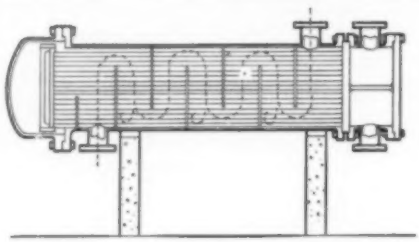
PUMP SUBCOMMITTEE of the A.I.Ch.E. studying a performance code for pumps handling chemical fluids is about ready to report significant progress, according to Robert L. Jacks, chairman . . . Seven different projects are operating under Jacks, including testing procedures & a questionnaire to industry on nomenclature, installation check list, mechanical design, materials of construction, etc. (discussed on page 38 of this issue) . . . Chairman of the Testing Committee is W. R. Marshall, Jr., of the University of Wisconsin.

MISCELLANEOUS . . . Lincoln T. Work appointed as an alternate to the A.S.A. Standards Council; Charles Lapple appointed to an A.S.M.E. committee on air- & gas-cleaning equipment; J. C. Elgin to National Research Council; C. Rogers McCullough to an E.J.C. task committee on nuclear problems; & Ralph A. Morgen, Sr., as official representative to E.C.P.D. for a three-year term . . . George O. Löf represented the Institute at the dedication ceremonies of the United States Air Force Academy at Denver, Colorado.

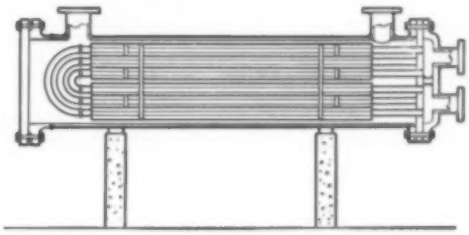
F.J.V.A.

BROWN FINTUBE'S

BETTER DESIGN MEANS BETTER PERFORMANCE



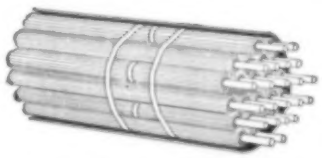
• Sectional View of Conventional Bare Tube Heat Exchanger Showing the Transverse Baffles that require the flow to make a series of 180° Bends, Resulting in Substantial Pressure Drop; Adding Unnecessarily to Pumping Costs; and producing Back Eddies, where Entrained Solids can Settle Out, Further Reducing the Heat Transfer Efficiency, and Increasing Cleaning and Maintenance Costs.



• Sectional View of Brown Fintube Bundle Exchanger. Fluid Flows through Hundreds of Long, Straight, Narrow Passages in Intimate Contact with the Heat Transfer Surface. The Only Pressure Drop Occurring Results from the Impingement of Flow Against the Heat Transfer Surface, and the Bends as the Fluid Enters and Leaves the Unit, Minimizing Pumping Costs, also Cleaning and Maintenance.

BROWN FINTUBE'S DESIGN ELIMINATES BAFFLES

Minimizing Pressure Drop



• View Showing the Banding of Alternate Fintubes to Prevent "Nesting", and Outer Bands that Produce a Tight, Compact Bundle of Long, Narrow, Straight Passages.

● The "bundle" in a Brown Fintube Exchanger consists of our integral "one-piece" fintubes connected with return bends; the other ends rolled into a tube sheet. A metal band strapped around each alternate fintube prevents "nesting", and the entire assembly is then banded tightly together.

This construction produces hundreds of long, narrow, straight passages, through which the fluid flows. Carefully controlled velocities develop a turbulent flow, keeping heat transfer coefficients in a desirable range. There are no baffles, as when bare tubes are used, with their 180° bends to cause pressure drop, and create back eddies where entrained solids can settle out. In Brown Fintube exchangers, pressure drop results *only*, from the impingement of the fluid against the heat transfer surface, and the bends entering and leaving the unit.

The "one-piece" fintubes, available in carbon steel, alloy or non-ferrous metals, have 6 or 8 times more surface than plain bare tubing. They transfer more heat per lineal foot than plain bare tubing, saving space and weight;—and at lower temperatures per square foot of surface, preventing damage to heat sensitive materials.

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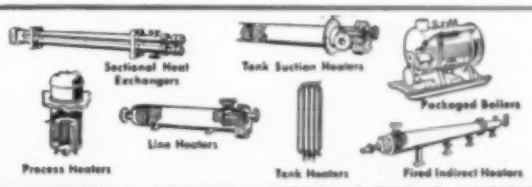

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How to control **shaft whip** *when you mix fluids*

This is a picture of how *not* to mix fluids.

You know the phenomenon. A three-inch steel shaft, suspended from a rigid mount, is rotating at a speed close to its natural vibration frequency. Without warning, the shaft begins to whip back and forth like a pendulum—farther and farther, faster and faster—until it snaps.

If this happens inside one of your tanks, you're in for a costly repair bill.

It *can't* happen when you mix with LIGHTNIN Mixers.

How to beat shaft whip

We've tortured hundreds of perfectly good mixer shafts in our lab, just to make sure *you'll* never break one. Our engineers know just how fast a shaft and impeller can rotate, in liquid or in air, without getting too close to the "critical speed." That goes for shafts of any material, any diameter, any length.

How else does this give you better mixing? Well, if you can use a long overhung shaft in a tank, without having to steady it at the bottom, you avoid the upkeep and operating problems of a steady bearing. That can be a big item if you're mixing corrosives or abrasives.

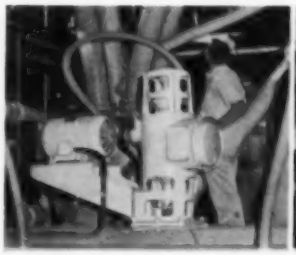
Then, too, if you're using a rotary mechanical seal on a closed tank, you'll want the shaft to run true at all times, to minimize wear on the seal faces.

Here's why you save

We can tell you just how long a shaft, of any diameter, you can use without going to a steady bearing; or conversely, what diameter a shaft of given length should have if you want to keep runout within well-defined safe operating limits.

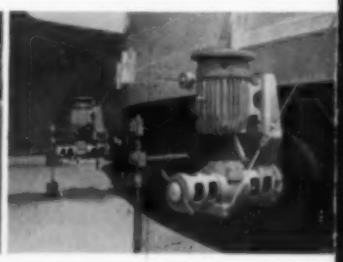
This is just one reason why you save time and cost by mixing with LIGHTNINS. You avoid risk, too. Every LIGHTNIN Mixer is unconditionally guaranteed to do the job for which it is recommended.

Why not find out, today, how easy it is to get the fluid mixing results you want? Just call your LIGHTNIN representative (listed in Chemical Engineering Catalog). Or write us for specific information that will help you.



HANDLE ALMOST ANY fluid mixing job with these versatile Series "E" LIGHTNIN Mixers. You can get them in sizes from 1 to 500 HP; for open or closed tanks, top or bottom entering; in hundreds of power-speed combinations.

MAKE ANY OPEN TANK an efficient mixing vessel, by adding a LIGHTNIN Portable Mixer. Thousands in use, many for 20 years and more. Thirty models, ⅛ to 3 HP.



IN LARGE TANKS (up to 6 million gallons) you can mix, blend, circulate, suspend solids efficiently with LIGHTNIN Side Entering Mixers. No shutdowns are ever necessary to repack stuffing box or replace mechanical seal. Sizes 1 to 25 HP.

Get these helpful facts on mixing: cost-cutting ideas on mixer selection; best type of vessel; installation and operating hints; full description of LIGHTNIN Mixers. Free—no obligation. Just check data you want, tear out and mail to us today with your name and company address.

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